CHARACTERIZATION OF USED OIL IN STORMWATER RUNOFF IN CALIFORNIA

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Joan E. Denton, Ph.D., Director
Office of Environmental Health Hazard Assessment
California Environmental Protection Agency

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PREPARED BY

California Environmental Protection Agency
Office of Environmental Health Hazard Assessment (OEHHA)
Integrated Risk Assessment Branch (IRAB)
Linda Mazur
Carmen Milanes
Karen Randles
Chuck Salocks

REVIEWED BY

Val F. Siebal, Chief Deputy Director, OEHHA
George V. Alexeeff, Deputy Director for Scientific Affairs, OEHHA
David M. Siegel, Chief, OEHHA/IRAB

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Robert Erlich, Lahontan Regional Water Quality Control Board
Douglas Feay, Lahontan Regional Water Quality Control Board
Tony Felix, San Diego Regional Water Quality Control Board
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John Merrifield, Los Angeles County Department of Public Works
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Michael Roth, Santa Ana Regional Water Quality Control Board
John Short, North Coast Regional Water Quality Control Board
Ejigu Solomon, Los Angeles Regional Water Quality Control Board
Dana Stokes, California Integrated Waste Management Board
Kristin Yee, California Integrated Waste Management Board

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EXECUTIVE SUMMARY

Runoff from urban areas has been identified as one of the leading sources of water quality impairment of the nation's surface waters, having been associated with changes in flow, increased sedimentation, higher water temperature, lower dissolved oxygen, degradation of aquatic habitat structure, loss of fish and other aquatic populations, and decreased water quality. This runoff is the primary transport system moving pollutants from the landscape to wetlands, streams, lakes and coastal waters. Although the effects of runoff on specific waters vary and are often not fully assessed, pollutants carried by runoff are known to have potentially harmful effects on drinking water supplies, recreation, fisheries, and wildlife.

Among the pollutants in runoff are oil and oil byproducts, which are known to contain harmful constituents such as metals and polycylic aromatic hydrocarbons (PAHs). The extent by which these materials are polluting stormwater runoff and the ultimate receiving waters is largely unknown. In this report, the Office of Environmental Health Hazard Assessment (OEHHA) reviews stormwater monitoring data for the purpose of characterizing used oil pollution in stormwater runoff. Stormwater runoff refers to water transported through stormwater conveyance systems during and after storm events.

In 2004, about 58 percent of the 150 million gallons of lubricating oil sold in California was recycled; about 20 to 40 percent is assumed to be combusted or leaked as a result of use. Additionally, about 150 million gallons of industrial oil were sold, of which 33 million gallons (22 percent of volume sold) were recycled. Used oil that is leaked, spilled or improperly disposed of can be carried in stormwater runoff, eventually entering and threatening the environmental health of receiving water bodies. It has been reported that petroleum hydrocarbons in urban runoff as well as in aquatic sediment in urban areas are primarily associated with used crankcase oil.

Monitoring conducted by municipalities and industrial facilities pursuant to stormwater regulatory programs (more specifically, the National Pollutant Discharge Elimination System or NPDES stormwater program) provides a major source of data on urban stormwater quality. Among the pollutants this monitoring quantifies is "oil and grease," which is collectively regulated as a conventional water pollutant.

Direct comparisons of the oil and grease concentrations reported by the studies reviewed in this report are problematic due to differences in sampling protocols, analytical methods, quality assurance/quality control processes, data analysis and other factors between studies. Nevertheless, qualitative conclusions can be drawn about relative patterns that are evident from the data. While the concentrations show considerable variability, typical concentrations are generally less than 5 milligrams per liter (mg/l), and seldom exceed 10 mg/l.

In general, the highest oil and grease concentrations tend to be reported in runoff sampled from discrete sources (e.g., parking lots and industrial facilities) before dilution, partitioning, adherence to particulates, settling, and other fate processes occur. Among these discrete sources, higher oil and grease concentrations have been reported in runoff from industrial facilities than from highways and parking lots. While occasional "spiked" concentrations above 10 mg/l are reported for highways and parking lots, much higher levels in the thousands of mg/l have been reported for industrial facilities (in more recent years, maximum values have declined). Higher concentrations are often associated with industries whose operations involve vehicles, heavy equipment and engines, and petroleum product processing or use. These include transportation facilities, petroleum bulk stations, lubricating oil blenders and re-refiners, refuse industries, metal fabricators, and automobile dismantlers. Even with these industries, however, oil and grease concentrations show sporadic spikes, rather than consistently high levels. The occasional spikes may be the result of non-compliance with, or the ineffectiveness of engineering controls or best management practices.

Monitoring designed to characterize runoff from catchment areas with a predominant land use indicates that oil and grease concentrations tend to be higher in commercial areas (i.e. retail and office buildings) compared to areas with other land uses. Mean concentrations as high as 13 mg/l have been reported for commercial areas, compared to mean values ranging from 0 to 0.9 mg/l for agricultural areas, which tend to have the lowest oil and grease concentrations.

Oil and grease concentrations measured at mass emission monitoring stations (typically at outfalls to a receiving water body) by municipalities in Southern California were generally below 5 mg/l. In Los Angeles County, where watersheds ranged from the ultra-urban to the relatively undeveloped, annual mean oil and grease concentrations averaged over multiple years were very similar among all watersheds, although year-to-year variability within a watershed and differences between watersheds for certain years may be significant.

Finally, oil and grease concentrations reported in earlier studies (from around the 1980s to early 1990s) tended to be higher than in more recent studies. A possible explanation for this may be that less crankcase oil has been leaking from more recent years' vehicle fleets.

Data for Los Angeles County were used for deriving crude estimates of annual oil and grease loadings – i.e., the amount of oil and grease discharged into receiving water bodies each year. A simple, screening level calculation was used to estimate annual loadings as the product of pollutant concentration and runoff volume. Oil and grease loadings were estimated to range from approximately 1.7 million pounds to 13 million pounds annually for Los Angeles County. These values correspond to approximately 0.23 million to 1.8 million gallons of used oil. Using these estimated values, total loadings Statewide were derived mathematically to range from 16 million to 120 million pounds. This roughly corresponds to 2.2 million to 16 million gallons of used oil, with 6.1 million gallons as the estimated volume for an average runoff year. These volumes are about 3 to 25 percent of the 64 million gallons of lubricating oil sold but not recycled (and about 1 to 9 percent of the 176 million gallons of lubricating and industrial oil sold but not recycled).

It is difficult to establish the ecological and human health implications of the typical concentrations reported in runoff and the loading estimates for oil and grease. Numeric water quality criteria for aquatic life or human health protection have not been adopted for "oil and grease" for purposes of the Clean Water Act. However, numeric criteria for aquatic life protection have been established for some constituents found in used oil, i.e., arsenic, cadmium, chromium, lead, nickel and zinc (40 CFR 131.38). A screening level analysis performed by OEHHA showed that, at the typical oil and grease concentrations in runoff, these used oil constituents are likely to occur at concentrations up to five orders of magnitude lower than freshwater and saltwater aquatic life water quality criteria. Nevertheless, these constituents may pose a long-term risk to the aquatic ecosystem because of their tendency to accumulate in sediment over time.

The ecological effects of used oil discharges in stormwater runoff entering receiving water bodies are influenced not only by individual constituents, but also by multiple factors, including the presence of other chemicals, the type and size of the receiving body, the frequency and duration of the discharge, the potential for dispersion, and the biological diversity of the receiving water ecosystem. Complex environmental processes acting on the oil, along with the highly variable nature of the used oil discharge, present a challenge in assessing the impacts of the discharge on the aquatic ecosystem.

Human health impacts will depend upon whether or not exposures to constituents of concern occur from direct contact, ingestion of contaminated water or via the food chain. Studies linking adverse health effects in humans following exposure to used oil contaminants in the aquatic environment were not found.

The relationship between the estimated loadings and the amount of used oil that is improperly disposed of cannot be established. However, the amount of used oil in stormwater runoff can more likely be attributed to leaks and spills from vehicle engines and other equipment, or from industrial activities, than incidents of illegal disposal. Further, the monitoring that yields mass emissions data is unlikely to capture episodic incidents of illegal disposal.

OEHHA is unable to ascertain how close these estimates are to actual amounts of used oil in runoff being discharged into receiving water bodies. There is considerable uncertainty in the estimate, given limitations relating to how close the concentrations in the samples represent actual concentrations of the pollutant, the inability of the commonly used analytical method to distinguish between petroleum-based hydrocarbons and biological lipids, and the appropriateness of extrapolating statewide loadings from estimates derived for a single county. In the absence of a more refined analysis, however, these estimates can be used as a baseline for planning and mitigation purposes.

1.0 Introduction

Stormwater runoff is the primary transport system moving pollutants from the landscape to wetlands, streams, lakes and coastal waters. Runoff from urban areas has been identified as one of the leading sources of water quality impairment of the nation's surface waters. Problems associated with runoff include changes in flow, increased sedimentation, higher water temperature, lower dissolved oxygen, degradation of aquatic habitat structure, loss of fish and other aquatic populations, and decreased water quality due to increased levels of nutrients, metals, hydrocarbons, bacteria, and other constituents (U.S. EPA, 2005a). Although the effects of runoff on specific waters vary and are often not fully assessed, pollutants carried by runoff are known to have potentially harmful effects on drinking water supplies, recreation, fisheries, and wildlife (U.S. EPA, 2006).

The Office of Environmental Health Hazard Assessment (OEHHA) has conducted an evaluation of information on the presence of used oil in stormwater runoff in California; the presence of oil and oil byproducts is of concern because these materials are known to contain harmful constituents such as metals and polycylic aromatic hydrocarbons. Stormwater runoff, for purposes of this report, refers to water transported through stormwater conveyance systems during and after storm events.

The California Integrated Waste Management Board (CIWMB) reports that in 2004, approximately 150 million gallons of lubricating oil were sold in California, and about 87 million gallons were recycled; similarly, about 145 million gallons of industrial oil were sold, of which approximately 33 million gallons were recycled (CIWMB, 2006). About 20 to 40 percent of the lubricating oil sold is assumed to be combusted or leaked as a result of use. Improper disposal of used oil down storm drains, into lakes or rivers, or with garbage may also occur (CIWMB, 2003). Used oil that is leaked, spilled or improperly disposed of can be carried in stormwater runoff, eventually entering and threatening the environmental health of receiving water bodies.

The extent by which used oil and oil byproducts are polluting stormwater runoff and the ultimate receiving waters is largely unknown. Monitoring studies report oil concentrations in runoff from highways, industrial facilities and at the base of watersheds. Models have been developed to estimate pollutant loadings in stormwater runoff. In this report, OEHHA utilizes existing stormwater monitoring data to characterize sources of oil and grease released in stormwater runoff, typical concentrations found in stormwater runoff, and approximate amounts entering California's surface waters via runoff.

1.1 Approach

OEHHA searched for runoff monitoring data for lubricating oil, industrial oil, and used oil. Information sources included peer-reviewed publications; State, local and federal reports; and discussions with staff at the State Water Resources Control Board (SWRCB), Regional Water Quality Control Boards (RWQCBs), the California

Department of Transportation (Caltrans) and other entities. It was found that hydrocarbon compounds in stormwater are typically measured as "oil and grease," which can include animal fats, vegetable oils, soaps, and other biological oils, in addition to petroleum constituents. OEHHA thus compiled data on oil and grease, and evaluated these in order to select the datasets most appropriate for characterizing oil and grease pollution in California stormwater.

OEHHA also reviewed models currently used to estimate pollutant loadings in stormwater, or the mass of a contaminant carried in stormwater discharges into a receiving water body per unit of time. OEHHA applied a simple model to estimate oil and grease annual loads for Los Angeles County watersheds. These watersheds represent a wide range of land use characteristics – from "ultra-urban" to predominantly undeveloped. Pollutant loading estimates were calculated for minimum, average and maximum runoff volumes to reflect the variability in runoff amounts from year to year. A "unit load" of oil and grease in urban runoff was calculated in order to extrapolate to a statewide loading associated with urban areas. Comparisons were made with other oil and grease loading studies to determine how close the estimates in this report are to the loading estimates derived by other investigators.

2.0 Used Oil in Runoff: Environmental and human impacts

2.1 Sources of used oil in runoff

Petroleum hydrocarbons in urban runoff from different land use sites have been reported to be primarily associated with used crankcase oil (Latimer et al., 1990). This determination was based on laboratory analysis of hydrocarbons and the polycyclic aromatic hydrocarbons or PAHs they contain (the latter, referred to as the "PAH signature," was used to discriminate between virgin and used crankcase oils). The investigators found that the particulates in runoff were considerably enriched in crankcase oil compared to street dust, roadside soil and vegetation, and atmospheric deposition. One possible explanation for this is that the oil may be derived from wash-off of crankcase oil deposited by cars in the center of the travel lanes and/or direct dumping of oil down storm drains.

Another study (Brown, et al., 1985) characterized stormwater runoff and subsequent hydrocarbon distribution in receiving waters and sediments as part of the City of Tampa's Nationwide Urban Runoff Program. The hydrocarbon characterization of suspended particulate matter and sediments from Hillsborough Reservoir, River and Bay showed a dominance of crankcase oil-like material. The fact that the type of petroleum found in sediment (crankcase oil) very closely resembles that found in stormwater runoff strongly implicates runoff as the primary source of sediment contamination.

While the amount of oil leaked from vehicles is not known, one model developed in New Zealand estimates the rate of oil lost to roadways to be 2.8 ml of lubricating oil per 1,000 kilometers driven for cars and light commercial vehicles, and 2.1 ml per 1,000 kilometers for most buses (Ministry of Transport, 2002). Based on the oil loss rate for cars and light commercial vehicles and using the number of vehicle miles traveled in 2004 (Caltrans, 2004a), an estimated 210,000 gallons of lubricating oil per year may be leaked onto State highways*. This may be an overestimate, since New Zealand's fleet appears to be older – and thus more prone to leak -- than California's: the median age of New Zealand cars is about 10 years, compared to 5 years for California. (Ministry of Transport, 2004; DOF, 2004a).

Other sources of oil and grease in runoff include hydraulic fluid leaks from vehicles, and lubricant leaks from construction, farm and other off-road or heavy equipment. In addition, oils used in industrial processes may be discharged into storm drains, particularly when "best management practices" (BMPs) are not followed. BMPs are runoff control practices designed to reduce the pollutants contained in discharges to the storm drain system and/or receiving waters. Finally, the illegal disposal of used oil into storm drains may still occur when motor oil is changed by "do-it-yourselfers."

2.2 Constituents of concern

Crankcase oil consists primarily of a base lubricating oil with variable chemical composition, depending on the source of the crude oil and processes used during refining. Lubricating oil is a heavy end distillate of crude oil containing straight chain and branched alkanes (approximately 45 percent of total hydrocarbons), cycloalkanes (approximately 30 percent) and aromatic hydrocarbons (approximately 25 percent) (Potter and Simmons, 1998). Very small amounts of PAHs are present in newly refined lubricating oil. Various additives comprise 10 to 20 percent of the volume of finished lubricating oil. These additives may contain zinc, magnesium, molybdenum, phosphorus, sulfur and bromine compounds (U.S. EPA, 1984).

Used crankcase oil contains, in addition to the complex mixture of hydrocarbons and additives present in the formulated product, contaminants associated with its use as an engine lubricant. Sources of contamination include additive breakdown products (e.g., metals); engine "blow-by" (i.e., material which leaks from the engine combustion chamber into the crankcase where the oil resides); burnt oil, metal particles from engine wear; and incomplete products of combustion of gasoline (U.S. EPA, 1984). Used oil contains small amounts of arsenic, cadmium, chromium, lead and nickel. These substances have been shown to produce acute and chronic toxicity in aquatic organisms at extremely low levels (U.S. EPA, 2000a). In addition, these substances have been associated with a wide range of toxic effects in humans, including death following ingestion of large doses, cancer, and skin irritation.

Used motor oil can become "enriched" with PAHs during the operation of an automobile engine. These contaminants concentrate in lubricating oil via transfer from gasoline or diesel fuel as combustion products (Pruell and Quinn, 1988). In one study, total PAH concentrations increased until about 4,000 miles to 14.5 milligrams per gram used oil

* Oil loss rate: 2.8 ml/1,000 km;
Vehicle miles traveled (VMT) statewide in 2004: 180,153 million miles
[2.8ml/1,000km]*[1,000km/621miles]*180,153,000,000miles*0.00026gallons/ml = 211,000 gallons

(mg/g), after which the concentrations leveled out. A number of PAHs are classified as probably carcinogenic to humans (based on animal evidence) (IARC, 2004), and have been shown to affect survival, growth, reproduction, and induction of neoplasms in aquatic organisms (Environmental Canada, 1994).

Used oil is listed under Proposition 65 (Safe Drinking Water and Toxic Enforcement Act of 1986) as a chemical known to the State of California to cause cancer (Title 22, California Code of Regulations, Section 12000). Animal studies have shown an increased incidence of skin tumors in mice after long-term skin exposures to used mineral-based crankcase oil from gasoline-powered cars, with more tumors observed in mice exposed to oil from cars driven the longest distances. The increase in carcinogenicity was attributed to accumulation of PAHs in the oils, given the correlation between tumor incidence and the PAH content of the oil (Agency for Toxic Substances and Disease Registry, 1997). In support of this hypothesis, McKee and Plutnick (1989) reported no tumors in mice exposed to new motor oil.

2.3 Fate and transport in surface waters

Oil and grease in water may be free floating and form a sheen before dispersion and partitioning processes occur. The sheen observed in urban creeks and waterways and in parking lot or street runoff has often been the primary motivation to control oil and grease in stormwater runoff. Water quality criteria established by U.S. EPA pursuant to Section 304(a) of the Clean Water Act specify that oil and grease should not be present at levels that produce a visible oily sheen (U.S. EPA, 2004).

Oil and grease concentrations less than 1 mg/l can create sheen on surface waters due to the reflection of sunlight (CDS, 2005). The National Oceanic Atmospheric Administration has developed a general glossary of terms to describe the appearance of oil floating on the water (see Table 1). A light, almost transparent layer of oil is approximately 0.00004 millimeters (mm) thick; a slightly thicker layer, 0.00007 mm thick, appears as a silver sheen. A rainbow sheen that reflects colors can be approximately 0.0003 mm thick, and brown oil is a dull colored sheen that is typically a 0.1 to 1.0 mm thick layer of water-in-oil emulsion (NOAA, 1996).

Table 1. Oil spill observation glossary

Description of sheen	Approximate thickness of layer (millimeters)	Approximate volume of oil per area (liters/square kilometer)
barely visible	0.00004	50
silver sheen	0.00007	100
first color trace	0.0001	200
iridescent rainbow colors	0.0003	400
dull colors	0.001	1,200
dark colors	0.003	3,600
brown oil	0.10 – 1.00	---

Source: NOAA, 1996. Reproduced from the "Oil Spill Slide Rule," ©1985 Government Publishing Office The Hague/The Netherlands

In general, when oil comes into contact with water, a partitioning of various volatile compounds, PAHs and metals takes place. Depending on their chemical and physical characteristics, the various constituents are subjected to several fate processes, including volatilization, sinking, emulsification, agglomeration, photodegradation and biodegradation (ATSDR, 1997).

Investigators have reported 81 to 96 percent of the hydrocarbon load in stormwater runoff is attached to particulates, indicating that adsorption to particles is the primary method of pollutant transport (Stenstrom et al., 1984). During a rainfall, the particulates are washed into storm drains and may attach to matter and settle or eventually deposit in receiving water sediments. Concentrations of oil and grease and heavy metals are generally higher in the smaller particulate fractions (Barrett et al., 1995). These finer grains have lower settling velocities and remain in runoff longer than larger grains.

Schueler et al. (1994) reported that the bottom sediments of many small, highly urbanized estuaries are heavily contaminated with PAHs and metals and that runoff from urban hydrocarbon hotspots (e.g., gas stations, parking lots) appears to be a major contributing factor. Certain constituents of used oil, notably the PAHs and metals, have a tendency to accumulate in sediments and enter into the food chain. Since PAHs and metals enter waterways as a result of many human activities (e.g., combustion of fossil fuels followed by deposition of particles on watersheds and waterways), it is difficult to apportion the presence of these contaminants in aquatic sediments to a particular source (e.g., used oil in stormwater runoff).

2.4 Adverse effects of used oil in runoff

Petroleum constituents in stormwater runoff pose a subtle but continuous threat to aquatic ecosystems. Much of what is known about the impacts of petroleum hydrocarbons in the aquatic environment comes from studies of catastrophic oil spills and chronic seeps (e.g., leaking pipelines) (NRC, 2003). Field and laboratory evidence have demonstrated both acute lethal toxicity and long-term sublethal toxicity of petroleum products to aquatic organisms. The long-term sublethal effects of oil pollution refer to interferences with cellular and physiological processes such as feeding and reproduction which do not lead to immediate death of the organism (U.S. EPA, 1986).

A literature review conducted for the U.S. Geological Survey and the U.S. Department of Transportation (Buckler and Granato, 1999) of the biological effects of highway runoff on local ecosystems revealed numerous information gaps. It appears that the use of different methods from one study to another and a lack of adequate documentation preclude making quantitative comparisons among different studies. However, the authors stated that the available data indicate that constituents from highway runoff and from highway runoff sediments deposited in nearby receiving waters are found in the tissues of aquatic biota, which may affect the diversity and productivity of biological communities.

While the effects of oil and petroleum products have been unambiguously established in laboratory studies and after well-studied spills, determining the more subtle long-term effects on populations, communities and ecosystems at low doses and in the presence of other contaminants pose significant scientific challenges. The effects of a petroleum release are a complex function of the rate of release, the nature of the petroleum, and the local physical and biological character of the exposed ecosystems. Ecotoxicological responses are driven by the dose of petroleum hydrocarbons available to an organism, not the amount of petroleum released into the environment. Because of the complex environmental processes acting on the released petroleum, dose is rarely directly proportional to the amount released (NRC, 2003). Given these considerations, the ecological impacts of used oil in runoff discharges into receiving waters are difficult to establish.

Because "oil and grease" is not a definitive chemical category, and includes myriad organic compounds with varying physical, chemical and toxicological properties, U.S. EPA has not set numeric water quality criteria for oil and grease. For aquatic life protection, U.S. EPA specifies a level that is "0.01 of the lowest continuous flow 96-hour LC_{50} to several important freshwater and marine species, each having a demonstrated susceptibility to oils and petrochemicals." (The "LC_{50}" is the concentration that is lethal for 50 percent of the test organisms.) U.S. EPA also specifies that surface waters be virtually free from floating oils (U.S. EPA, 1986). The California Toxics Rule (40 CFR 131.38) specifies numeric criteria for aquatic life protection in freshwater and saltwater for some of the constituents of concern found in used oil (i.e., arsenic, cadmium, chromium, nickel, lead and zinc).

The potential human health impacts from used oil present in stormwater runoff are likewise difficult to estimate. Individual chemical constituents in petroleum products are known to be toxic to humans under certain exposure conditions: some of the PAHs and metals present in lubricating oil have been shown to be carcinogenic in animal studies and the adverse noncancer health effects of these and other constituents are well characterized. A major concern is that these petroleum constituents can deposit in aquatic sediments and enter tissues of invertebrates and fish. While fish are able to metabolize and eliminate PAHs, human ingestion of mollusks and other aquatic invertebrates that are unable to metabolize PAHs efficiently can represent a potential exposure route (ATSDR, 1995). Studies linking adverse health effects in humans following exposure to used oil contaminants in the aquatic environment have not been found.

3.0 Measuring Oil and Grease in Stormwater Runoff

3.1 Stormwater discharges: Regulatory background

Much of the published stormwater data have been generated to comply with water quality regulations. Among the regulated pollutants is "oil and grease" (40 CFR 401.16).

Since 1990, most stormwater discharges have been considered point sources that are subject to permit requirements pursuant to the National Pollutant Discharge Elimination System (NPDES) program (U.S. EPA, 1990). NPDES regulations are promulgated by the U.S. Environmental Protection Agency (U.S. EPA). In California, the NPDES Program is administered by the State Water Resources Control Board and the nine Regional Water Quality Control Boards (SWRCB, 2005a, b).

The NPDES stormwater permit regulations cover stormwater discharges from:

- **municipal separate storm sewer systems (MS4s)** in urbanized areas (An MS4 consists of a conveyance or system of conveyances -- including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains -- designed for collecting and conveying stormwater, which is not a combined sewer nor part of a publicly owned treatment works, and which is owned or operated by a state or local government entity (see Figure 1) (40 CFR 122.26(b)(8)).);

- **industrial facilities** in any of the 11 categories that discharge to an MS4 or to waters of the United States; and,

- **construction** activity that disturbs land areas of one or more acres.
  (U.S. EPA, 2003)

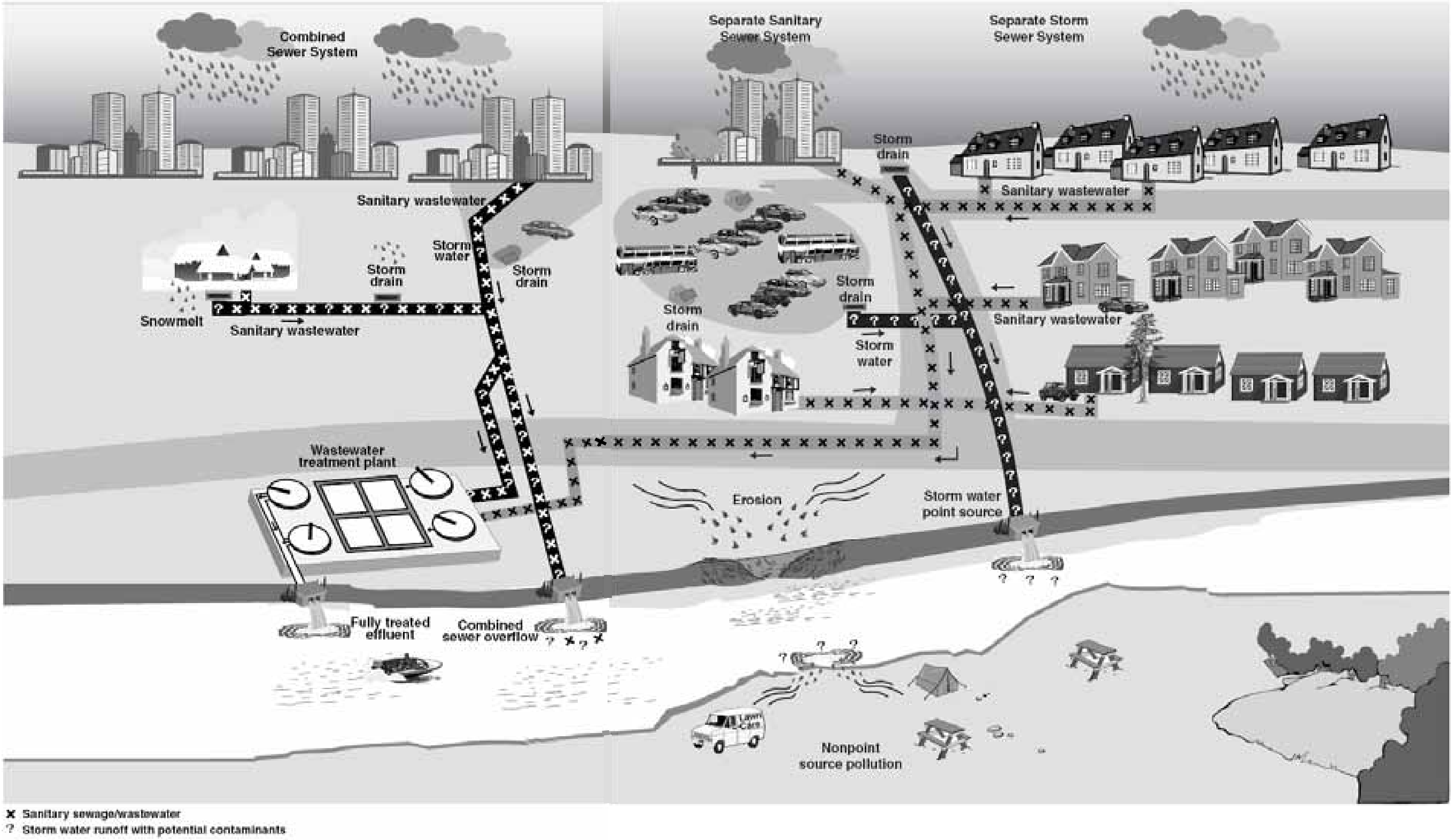
Details on the NPDES stormwater program can be found in Appendix A.

3.2 Factors affecting pollutant levels in stormwater runoff

Many factors influence the quality of stormwater runoff. Complex interactions between these variables obscure simple correlations between individual variables and water quality (Barrett et al, 1995).

Pollutant concentrations in stormwater exhibit a high degree of variability, not only between storms, but also within a storm. Among the major factors affecting stormwater quality is precipitation. Variations in rainfall intensity (the depth of precipitation per unit time) influence runoff rate, pollutant washoff rate and transport, sediment deposition and re-suspension, and other physical factors that collectively determine pollutant concentrations and stormwater flow rate at a given monitoring location at a given point in time. In addition, the time interval between storm events (often measured in terms of the antecedent dry period) has been shown to greatly influence levels of pollutants in runoff. (U.S. EPA, 2002)

Figure 1. Combined vs. separate storm sewer systems draining an urban watershed



(Source: GAO, 2001)

Typically, the major load of total pollutants occurs shortly after the onset of a rain event. When a disproportionately higher pollutant load is associated with discharge from the first portion of a storm event, a "first flush" is said to occur; a seasonal first flush occurs when the higher load is associated with the first storm of a season. Pollutants that accumulated on streets, gutters, and land between rain events are washed off and essentially "pulsed" into receiving waters via storm drains. A seasonal first flush phenomenon may be especially pronounced in areas of California, where there is little or no rainfall from May through September. This rainfall pattern creates a long period for pollutant build-up such that the initial storm of the rainy season may have higher pollutant concentrations than in later events (Lee et al., 2005).

The size of the drainage area appears to influence the occurrence of a first flush. In a large watershed, where stormwater is transported over large distances and pollutants diluted, first flushes are much less likely to occur. In contrast, smaller, discrete areas, particularly those with a high degree of imperviousness, are more likely to exhibit first flush. For example, first flush has been demonstrated for highway catchments (Stenstrom and Kayhanian, 2005) and parking lots (Tiefenthaler, et al., 2001). Tiefenthaler, et al. conducted a study of parking lot runoff generated by simulated rainfall in Long Beach, California. Runoff samples collected during the first 10 minutes of a rain event contained the highest constituent concentrations. Longer simulated storms appeared to dilute parking lot runoff and significantly lowered the average concentrations of most constituents.

The geographic and physical characteristics of the watershed – including the type and intensity of land use, degree of imperviousness, tree cover, soil type, slope and drainage density -- are all important determining factors in the generation of nonpoint pollution (Brezonik and Stadelmann, 2002). With urban development, natural vegetated pervious ground cover is converted to impervious surfaces, which can neither absorb water nor remove pollutants. The increased volume, velocity and discharge duration of stormwater runoff from urbanized areas will transport greater amounts of pollutants into receiving waters.

The type of stormwater conveyance system will also affect stormwater quality. For example, conventional curb and gutter systems provide a direct conduit to natural water bodies and may act to collect and concentrate pollutants. Alternatively, curb and gutter systems that empty into drainage swales will act to collect and filter runoff before it can enter underground drainage systems (BASMAA, 1999).

Potential sources and activities releasing pollutants into stormwater runoff are closely related to land use in the watershed. For example, pollutant concentrations have been shown to increase with higher traffic levels (Caltrans, 2004b). The often transitory and unpredictable nature of many pollutant sources and release mechanisms (e.g., spills, vehicle-washing runoff, dumping) further contribute to variability in contaminant concentrations (U.S. EPA, 2002).

3.3 Stormwater runoff sampling

Although stormwater runoff can result from pavement washing, irrigation and other activities (dry weather flows), this report evaluates oil and grease in stormwater resulting from wet weather events. Wet-weather sampling is critical in urban runoff pollution prevention and mitigation planning because most of the source loadings occur in wet weather (U.S. EPA, 1993). Wet-weather generated runoff can contribute large pulses of pollutant load and can make up a significant percentage of long-term pollutant loads from urban/suburban areas (Silverman et al., 1985).

Stormwater regulations establish specific requirements for sampling, including when and where samples are to be collected, and the sample type and technique (i.e., manually or by automatic sampler) for collecting certain pollutants (U.S. EPA, 1992). "Sample type" refers to either "grab" or composite samples. A grab sample is a discrete, individual sample taken within a short period of time (usually less than 15 minutes). Analysis of grab samples characterizes the stormwater quality at a given time of the discharge. A composite sample is a mixed or combined sample that combines a series of individual and discrete samples of specific volumes at specific intervals. Composite samples characterize the quality of a stormwater discharge over a longer period of time, such as the duration of a storm event.

When monitoring stormwater for oil and grease, a grab sample is generally collected, as required by U.S. EPA guidance. An automated composite sample is not appropriate because the oil and grease in combined samples tends to accumulate inside the tubing and other components of the sampling equipment.

3.4 Analytical methods

Hydrocarbon compounds in stormwater are typically measured as "oil and grease," with no differentiation between fractions (i.e., specific hydrocarbon components) (Strenstrom et al., 1985). The term generally refers to biological lipids and petroleum-based hydrocarbons, which have similar physical properties and solubility in organic solvents. Hence, oil and grease may include animal fats, soaps, vegetable oils, waxes, esters, and fatty acids in addition to petroleum constituents.

The most common analytical method currently used for analyzing runoff for oil and grease is U.S. EPA Method 1664. This method is a liquid/liquid extraction (using normal-hexane), followed by mass determination by weight (gravimetry) for the quantitation of oil and grease in water (U.S. EPA, 1999; U.S. EPA, 2002). The method detection limit is 1.4 mg/l and the minimum level of quantitation is 5.0 mg/l. Most of the stormwater runoff monitoring studies evaluated for purposes of this effort reported detection limits of 5.0 mg/l; a few studies reported a detection limit of 1.0 mg/l. Another method used is U.S. EPA Method 413.1, which uses 1,1,2-trichloro-1,2,2-trifluoroethane (Freon-113) as the extraction solvent, and gravimetry (40 CFR 136.3).

In general, gravimetric methods are not as sensitive as more sophisticated instrumentation techniques because the more volatile constituents of oil and grease can be lost during the solvent evaporation stage of sample preparation. In an effort to better estimate the amounts of motor oil in stormwater runoff, some entities measure "total petroleum hydrocarbons (TPH) as motor oil" instead of oil and grease. For example, the Sacramento County Stormwater Quality Program recently began to monitor for various petroleum hydrocarbon fractions (Sacramento County, 2004). TPH concentrations may provide a more representative measure of the amount of petroleum-based compounds in stormwater than oil and grease concentrations.

3.5 Sources of uncertainty in stormwater monitoring data

The primary sources of uncertainty associated with stormwater monitoring data lie in the methods used for sampling and analysis. The use of grab samples to determine concentrations of oil and grease in runoff (described in section 3.3) may not be representative of the runoff generated by that storm event. For example, if first flush effects are present, grab samples collected subsequent to the first flush flows will likely yield lower contaminant concentrations. Alternatively, a grab sample that captures peak concentrations represents an overestimation of the average concentration for the storm event. In a study by Tiefenthaler et al. (1999), the magnitude of within- and among-storm variability observed in frequent sampling of stormwater runoff demonstrated that representative oil and grease concentrations cannot be characterized by a limited number of samples. Storms that are monitored using a single grab sample, or wet seasons that are monitored by a single storm event, may not adequately characterize pollutant concentrations.

The physical properties of oil and grease can influence its measurement in stormwater. Oil and grease tends to adhere to particles, litter and other materials, may accumulate and subsequently be released. A stormwater sample that captures this accumulated oil and grease will yield a concentration much larger than would otherwise be found.

Given the limitations associated with grab samples, Stenstrom and Kayhanian (2005) have suggested the use of chemical oxygen demand (COD) and dissolved organic carbon (DOC) as more accurate surrogates for characterizing levels of oil and grease from highway stormwater runoff. The investigators found levels of COD and DOC to be highly correlated to oil and grease concentrations in highway runoff. Since COD and DOC samples are collected as automatic, composite samples, analytical results for these parameters more closely represent the entire storm event than a single or even multiple grab samples tested for oil and grease.

As discussed in section 3.4, the analytical methods commonly used for oil and grease do not distinguish among various petroleum-based or biological oils and therefore do not specifically measure used oil. Hence, the concentrations of "oil and grease" reported may overestimate the amounts of petroleum-based oil. Researchers are seeking more reliable methods to quantify petroleum hydrocarbons in runoff and atmospheric particulates as a result from lubricating oil blowby from combustion sources. This includes the use of "biomarker signature" chemicals, such as hopanes and steranes found in petroleum products derived from crude oil (Young, et al., 2004; Graham, et al. 2004).

4.0 A review of oil and grease data reported

This section summarizes data on oil and grease levels reported in stormwater runoff from monitoring conducted pursuant to NPDES requirements, as well as from other studies. Table 2 is a compilation of the data reviewed in this section. Data are presented for: (1) monitoring of highways, parking lots and industrial facilities to characterize discrete sources of stormwater discharges; (2) monitoring of runoff from specific land uses in urban areas; and (3) monitoring of discharges into receiving waters. Figure 2 depicts the various types of monitoring that yielded these data.

4.1 Oil and grease in runoff from discrete sources

Motor vehicles are important sources of oil and grease releases into the environment. Hence, areas or facilities where a large number of vehicles are regularly present, particularly over extended periods of time, are likely to be major contributors to oil and grease pollution in stormwater runoff. Parking lots and highways are examples of such areas. These areas are generally considered as continuous sources of oil and grease in runoff.

Industrial facilities represent another discrete source of oil and grease, with certain types of industries more frequently associated with higher concentrations than others. The data indicate that industrial facilities can be associated with elevated but sporadic releases of oil and grease.

4.1.1 Parking lots

Concentrations of oil and grease in stormwater runoff from parking lots can range from below detection to high "spiked" values. Parking lot data were found for commercial and retail establishments.

An early study of oil and grease concentrations in runoff in Richmond, California (Strenstrom et al., 1984) found the highest concentrations to be associated with the parking lot of a large-scale commercial property with a department store (range 7.9 to 31.3 mg/l, mean = 16.1 mg/l). The concentration was four times higher than the sampling station in a residential area, which had the lowest concentration (see Table 2).

Table 2. Reported oil and grease concentrations (mg/l) from selected studies.
The table lists mean concentrations (unless otherwise noted) and, when available, the standard deviation (italicized text in parentheses) and the range.

	Source monitoring				Land use monitoring				Reference
Location	Parking lot	Highway	Industrial facility	Other source	Residential	Commercial	Industrial	Other land use	
Richmond, CA									Strenstrom, et al., 1984
• Mouth of watershed								7.9 *(4.7)* 3.5-15.7	
• Trucking distribution center			7.3 *(2.4)* 3.0-9.5						
• Large commercial parking	16.1 *(7.6)* 7.9-31.3								
• Mixed residential/ commercial street and three service stations								10.9 *(2.4)* 8.3-14.1	
• Residential					3.9 *(4.5)* 0.8-13.5				
Los Angeles, CA									LASGRWC, 2005
• Office building parking lot	1 *(0.3)* ND-2.0								
• Public park parking lot	5 *(0.1)* 1.5-5.1								
• Metal recycler			210 *(260)* 29-390						
• Paper, glass plastic and metal recycling facility			6 *(5)* 2.2-48						
• School yard				2 *(0.9)* ND-3.6					
• Residence driveway	26.8 *(35.6)* 1.6-52								
Alabama									CERS, 2000
• Agriculture								0 all <1	
• Light industrial							9.5 <1-50.4		
• Residential					1.5 <1-4.8				
• Low-traffic commercial parking lot	1.5 <1-3.8								
• Moderate to high traffic parking lot	0.3 <1-1.6								

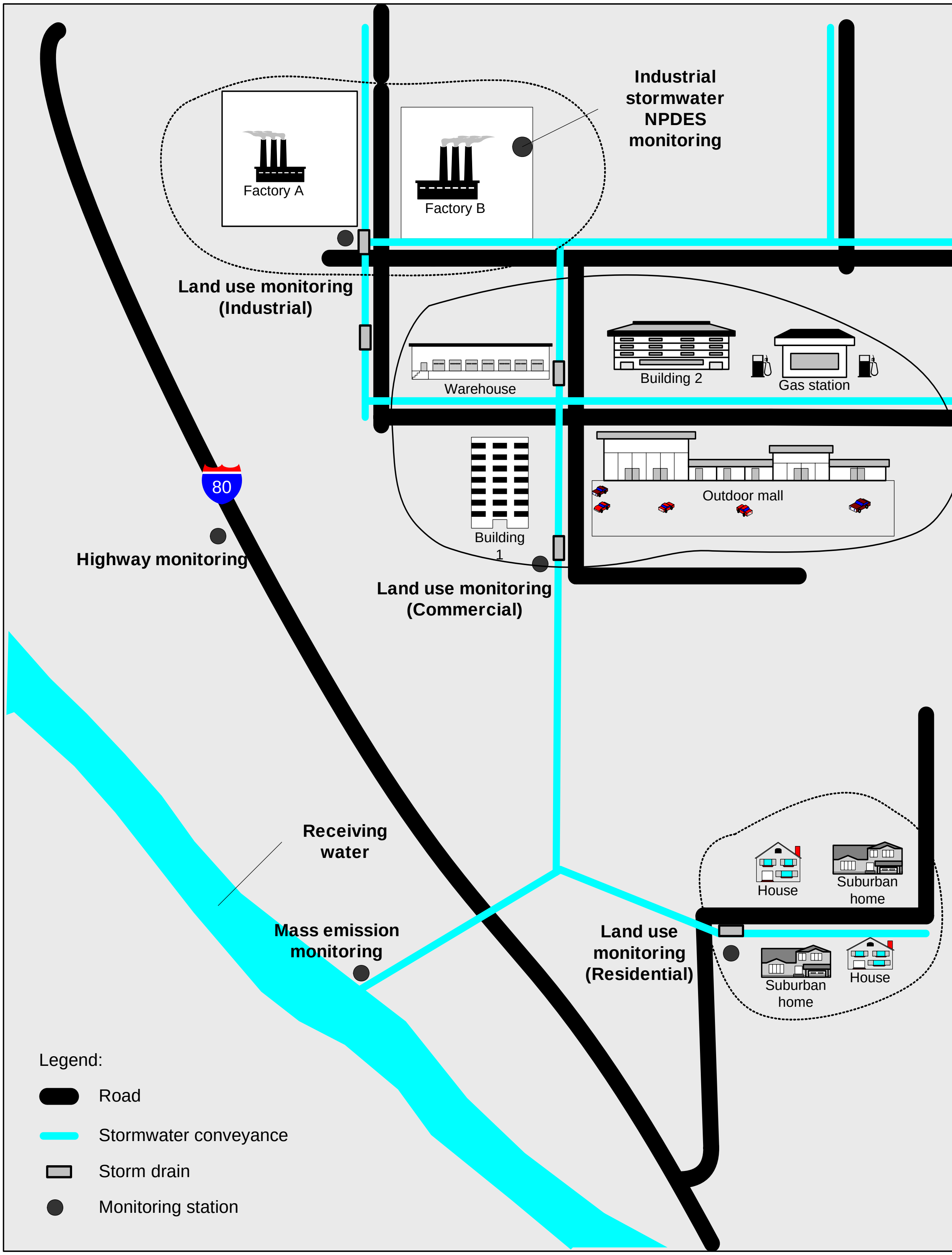
Location	Source monitoring				Land use monitoring				Reference
	Parking lot	Highway	Industrial facility	Other source	Residential	Commercial	Industrial	Other land use	
Washington, D.C.									Rabanal et al., 1995
• National Arboretum parking lot	0.7[a] 0.3-2.4								
• Gasoline station				4.2[a] 1.2-5.5					
• residential					1.9[a] 0.8-4.7				
• fast food parking lot	7.0[a] 2.7-5.6								
CA Highways									
• Statewide		4.9 *(11.4)* ND-61							Caltrans, 2003a
• Tahoe Basin		18 4-61							Caltrans, 2003b
• I-405, Los Angeles		8 [a]							Driscoll, et al., 1996
• Hwy 50, Sacramento		9[a]							Driscoll, et al., 1996
• I-680, Walnut Creek		11[a]							Driscoll, et al., 1996
Nationwide		15							Driscoll, et al., 1996
North Carolina highways									Wu, et al., 1998
• 100% impervious ADT[b] 25,000		4.4							
• 61% impervious ADT 21,500		2.5							
• 45% impervious ADT 5,500		1.3							
Austin, TX highways		0.4-2.0[c]							Irish, et al., 1995
California industrial stormwater NPDES facilities									SWRCB, 2005c
• 2000-2001			11.2 *(39.8)* ND-1640						
• 2001-2002			13.7 *(60.8)* ND-1802						
• 2002-2003			12.5 *(55.2)*						

[a] Median value
[b] ADT =Average daily traffic (no. of vehicles)
[c] Median event mean concentrations

Location	Source monitoring				Land use monitoring				Reference
	Parking lot	Highway	Industrial facility	Other source	Residential	Commercial	Industrial	Other land use	
			ND-1664						
Nationwide (U.S.)		8.0[1], 4.0[a]			3.9 [a], 4.4[a]	4.7[a], 5.0[a]	5.0, 4.5[a]	Open space, 1.3[a] Mixed open space, 6.0[a] All land uses, 4.3[a] ND–1,100	Pitt, et al., 2004
Fresno, CA					Single dwelling: 3 *(2.5)* 1-8 Multiple-dwelling: 1.8 *(1.2)* <1-5	4.9 *(6.5)* ND-26	10.6 *(19.9)* ND-80		Oltmann, et al., 1987
Los Angeles County, CA					High-density single family residential 1.3	3.3	Light Industrial 1.7	Transportation 3.1	LADPW, 2000 (Table 4-12)
Ventura County, CA					3.2, 4.7	5.7	2.5, 3.4	Agricultural 0.9	Ventura County, 2001
La Mirada, CA (2005)					ND-3.0	ND-2.9	ND-2.8		La Mirada, 2005
Texas (1993-1994) • Galveston Bay National Estuary • Dallas- Fort Worth • Corpus Christi					 4.0 1.0 1.7	 13.0 2.0 9.0	 <1.0 3.0	 Transportation 0.4	Baird, et al., 1996
Long Beach • Mass emissions								22-27	Long Beach, 2002
Los Angeles • Mass emission								1.9-3.7	LADPW, 2005
San Diego, CA • Mass emission								1.4-4.3	San Diego, 2005
Ventura, CA • Mass emission								2.4-2.5	Ventura County, 2001

[1] Median value

Figure 2. Stormwater monitoring



Stormwater runoff samples were collected over a four-year period at a schoolyard, commercial office building parking lot, public park parking lot, private residence driveway and two industrial sites at the detention basin inlets as part of the Los Angeles Basin Water Augmentation Study (LASGRWC, 2005). As shown in Table 2, the mean oil and grease concentration was lowest at the office building parking lot (1 mg/l), and highest at one of the industrial sites (210 mg/l at the metal recycler). The mean concentration at the public park parking lot was 5 mg/l, and at the driveway to the residence, an unusually high level (as can be seen from Table 2, concentrations reported for residential neighborhoods are typically below 5 mg/l) of 26.8 mg/l.

In an Alabama study characterizing runoff from different types of urban and suburban catchments, oil and grease concentrations reported from parking lot runoff were below 5 mg/l (CERS, 2000). Samples were collected from 1997 to 1999 from an agricultural field, light industrial site storm drain, a residential subdivision and two commercial parking lots. The highest concentrations (over 50 mg/l) were detected at a location draining runoff from an area that included a rubber tire manufacturer. The relatively higher oil and grease levels found at this location may be related to the use of petroleum products at the tire facility.

A study of urban stormwater runoff at four small catchments in the Washington, D.C. area was carried out in 1992-1993 (Rabanal, et al., 1995). The sampling locations included an office parking lot, a commercial fueling station, a fast food restaurant parking lot and a residential street (see Table 2). Median oil and grease concentrations were below 5 mg/l, except for the fast food parking lot (median = 7.0 mg/l). The authors noted that the higher concentrations at the fast food parking lot were likely due to the oil and grease used during food preparation from the solid waste handling area.

4.1.2 Highways

Monitoring conducted by the California Department of Transportation (Caltrans) provides a major source of highway runoff data for the State. As part of its NPDES permit requirements, Caltrans conducts monitoring and research studies on the constituents of stormwater runoff from its facilities, their impacts on receiving water bodies and the effectiveness of best management practices. Caltrans facilities include highways, maintenance yards, park and ride lots, and construction sites. In addition to characterizing stormwater discharges statewide, Caltrans also conducts specialized studies that investigate specific aspects of stormwater quality, such as the effects of traffic congestion, differences in pollutant concentrations attributable to the first flush phenomenon, and stormwater toxicity (Caltrans, 2004b).

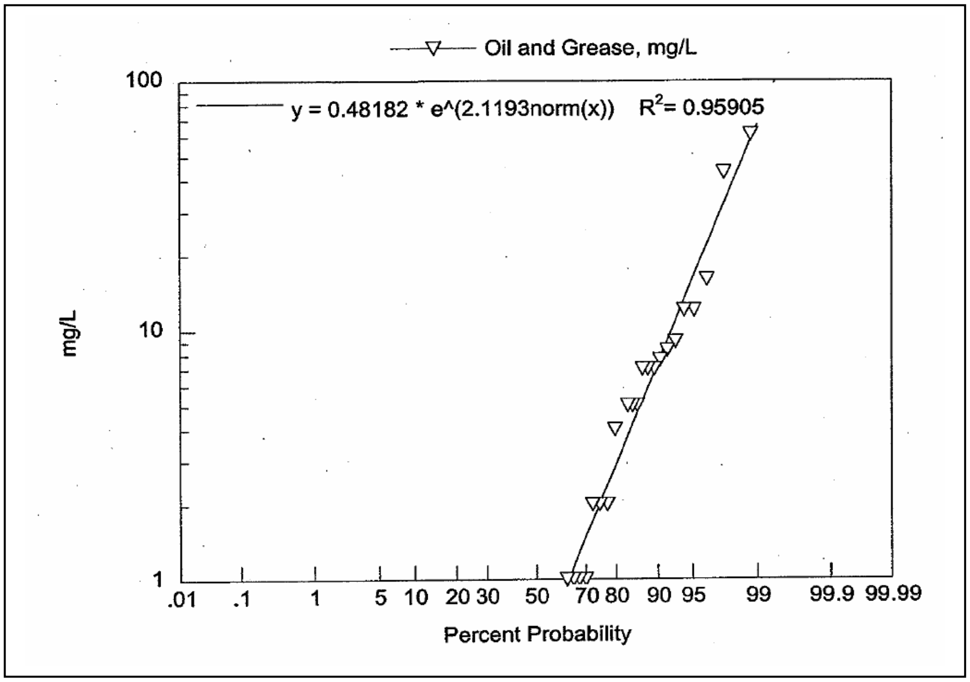
In November 2003, Caltrans published the results of a comprehensive set of studies to characterize stormwater runoff from transportation facilities throughout the State. These discharge characterization studies included monitoring for oil and grease at certain sites. Oil and grease was detected in 29 percent of the 49 samples collected during the 2000/2001 to 2002/03 monitoring years. Among the samples in which oil and grease was detected, concentrations ranged from 5 to 61 mg/l; a mean of 4.95 mg/l was estimated for all samples, including non-detects (i.e., samples for which laboratory analysis indicates that the constituent is not present) (Caltrans, 2003a). As shown in Figure 3, concentrations for about 90 percent of the samples were at or below 10 mg/l.

Caltrans notes that transportation facilities with higher traffic levels produce higher pollutant concentrations in runoff than others with lower traffic levels. It was determined that annual average daily traffic (AADT) is one of the most significant factors affecting pollutant concentrations in runoff from transportation facilities, particularly highways and toll plazas. An analysis of Caltrans highway runoff data for 1997 to 2001 showed that the average concentration of oil and grease was strongly correlated with AADT (Kayhanian, et al., 2003).

Oil and grease concentrations in highway runoff appear to show regional differences. Among the special studies conducted by Caltrans is a three-year study characterizing highway runoff in the Tahoe basin and assessing the effectiveness of sand traps in reducing pollutant concentrations. For the 27 samples collected, oil and grease concentrations ranged from 4 to 61 mg/l in untreated highway runoff, with a mean of 18 mg/l and a median of 12 mg/l (Caltrans, 2003b). As with over half of the monitored constituents, oil and grease levels in this study were typically higher than statewide levels. The study also found that concentrations from the low elevation sites (mean = 23 mg/l) were generally higher than from sites at high elevation -- i.e., over 200 vertical feet over Lake Tahoe (mean = 13 mg/l). Likewise, concentrations at urban sites (mean = 26 mg/l) were generally higher than at rural sites (mean = 14 mg/l).

As part of the National Highway Runoff Data and Methodology Synthesis, the U.S. Geological Survey conducted a review of existing data (published in the 1970s to the mid-1990s) on semivolatile organic compounds (SVOCs) in highway runoff and urban stormwater, with particular emphasis on highway studies (Lopes and Dionne, 1998). Petroleum hydrocarbons, oil and grease, and polycyclic aromatic hydrocarbons in crankcase oil and vehicle emissions are the major SVOCs detected in highway runoff and urban stormwater. Four studies reported oil and grease concentrations in highway runoff ranging from 1 to 480 mg/l; two of the four studies reported mean values (3.65 and 16.05 mg/l).

Figure 3. Oil and grease concentrations in highway runoff, frequency distribution



Source: Caltrans, 2003

An earlier study by the Federal Highway Administration (FHWA) assembled monitoring data from 993 separate storm events at 31 highway runoff sites in 11 states (Driscoll, et al., 1990). The data were collected from various studies that were either sponsored by FHWA or conducted by state transportation departments with support provided by FHWA. Oil and grease was monitored at only six sites, and at these for relatively few total events. Typical concentrations were 5 to 10 mg/l, although a median concentration as high as 53 mg/l was reported for one of the sites. The mean concentration for all sites was 15 mg/l. Three of the study sites were located in California: Interstate 405 in Los Angeles, Highway 50 in Sacramento and Interstate 680 in Walnut Creek. The median concentrations of oil and grease reported for these sites were 8, 9 and 11 mg/l, respectively.

A study conducted in Charlotte, North Carolina monitored oil and grease concentrations at three highway segments typical of urban, semi-urban and rural settings (Wu, et al., 1998). Monitoring was conducted from August 1995 to July 1996. The highest mean oil and grease concentration, 4.4 mg/l, was reported for the site with 100 percent imperviousness and the highest average daily traffic volume (25,000 vehicles per day). The site with 61 percent imperviousness and similar traffic volume (21,500 vehicles per day) reported a mean concentration of 2.5 mg/l. The lowest mean concentration, 1.3 mg/l, was reported for the least impervious site (45 percent) with the lowest traffic count (5,500 vehicles per day).

A four-year study investigated stormwater runoff quality from highway pavements in and near the recharge zone of the Barton Springs segment of the Edwards Aquifer in Austin, Texas (Irish, et al., 1995). A total of 35 simulated rainfall events and 23 natural storm events were sampled over the course of the study. Median event mean concentrations (EMCs) of oil and grease in runoff ranged from 0.4 to 2.0 mg/l. EMCs for natural storm events were found to be higher than simulated storm events, likely due to the fact that, unlike simulated events, samples are not collected over the entire duration of most natural storm events. Concentrations of constituents were observed to be higher in the earlier stages of the runoff event, and it is likely that the EMCs for natural storm events would have been lower had the entire storm been sampled.

4.1.3 Industrial facilities

Stormwater discharges from certain industrial facilities are subject to the requirements of a permit under the NPDES Program. California's nine Regional Water Quality Control Boards administer the industrial stormwater NPDES Program, which covers over 7,000 facility permits statewide (SWRCB, 2005d). A more detailed discussion of regulatory requirements and oil and grease data reported by industrial facilities are presented in Appendix B.

4.1.3.1 Statewide summary

Permitees are required to conduct visual inspections of stormwater discharges and to collect stormwater samples from pre-selected locations on the property. These samples are to be collected during the first hour of discharge from the first storm of the wet season and at least one other storm.

Analytical data in the Annual Reports submitted by each permittee to their Regional Board are incorporated into a statewide database (SWRCB, 2005c). A summary of the data reported statewide for oil and grease from the 2000-2001 to 2002-2003 reporting years is presented in Table 3. For these years, the data are predominantly from the San Francisco Bay, Central Coast, Los Angeles, and Santa Ana Regions. These years are presented due to the limited number of reports in the database prior to 2000 and for 2003-2004.

As shown in the table, oil and grease was detected in 76 to 80 percent of the samples. Mean values ranged from 11.2 to 13.7 mg/l (without non-detects, the mean values range from 13.8 to 17.2 mg/l), and the median for all the years is 5 mg/l. Figure 4 shows that the most frequently reported concentrations were 0 and 5 mg/l. The database does not provide information about the analytical detection limits for the samples; however, 5 mg/l is generally the limit of detection for the method used for oil and grease analysis (U.S. EPA Method 1664). Thus, it is likely that the high frequency of 5 mg/l may be a reporting artifact.

Table 3. Summary of oil and grease (O&G) data from *Annual Report for Storm Water Discharges Associated with Industrial Activities*

	Reporting Year*		
	2000-2001	2001-2002	2002-2003
Number of samples tested for O&G	5192	4987	4778
Percent detect	80%	80%	76%
Percent of O&G samples $\geq$ 15 mg/l benchmark value	16%	16%	17%
O&G concentrations, mg/l			
Minimum	0	0	0
Maximum	1640	1802	1664
Mean including non-detects*, mg/l *(Standard deviation)*	11.2 *(39.8)*	13.7 *(60.8)*	12.5 *(55.2)*
Mean without non-detects, mg/l *(Standard deviation)*	13.8 *(43.9)*	17.2 *(67.7)*	16.4 *(62.9)*
Median, mg/l	5	5	5
Mode	5	5	5

* Non-detects were considered to be zero when calculating the mean

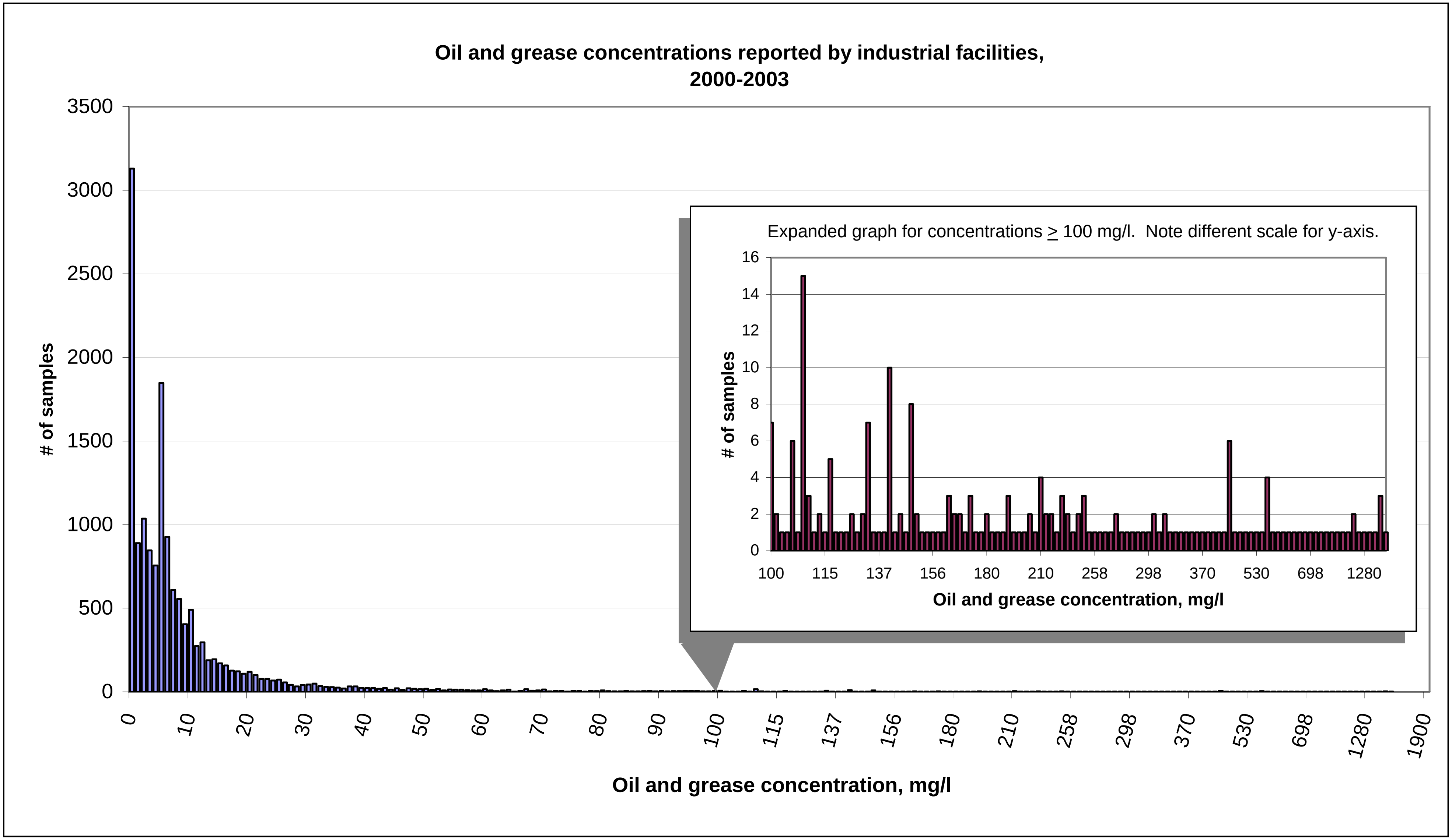
The data appear to indicate that the more highly urbanized regions -- i.e., Los Angeles, Santa Ana, and San Francisco Bay -- have a higher proportion of samples above the benchmark than the more rural Central Coast (see Appendix B). The Regional Boards in most instances have adopted a concentration of 15 mg/l as the level that may trigger inspections, and/or a requirement for facilities to re-evaluate the effectiveness of their best management practices. According to Regional Board staff, exceedances may often be attributed to poor maintenance or housekeeping practices. Generally, simple measures such as using spill response kits and drip pans, and covering equipment and other sources of oil and grease can effectively reduce releases (RWQCB, 2005).

Although about 85 percent of all the samples had concentrations at or below the benchmark level of 15 mg/l, significantly higher concentrations (over 100 mg/l) are occasionally reported. Maximum concentrations are as high as 1800 mg/l. Prior to the 2000-2001 reporting year, even higher oil and grease concentrations (as high as 33,000 mg/l) were found; however, such large spikes have not been reported since.

4.1.3.2 Industries that tend to have high concentrations of oil and grease

To identify industries that may be releasing the highest concentrations of oil and grease, samples with extremely high concentrations were selected from the statewide database for all reporting years (see Appendix B, Attachment 3). For purposes of selecting this subset of samples with extremely high oil and grease levels, OEHHA used a concentration of 400 mg/l as a benchmark (about 0.3 percent of samples tested for oil and grease were at or above this level). Industries with repeatedly high oil and grease concentrations include those that use or process petroleum products (e.g., transportation

Figure 4. Oil and grease data from *Annual Report for Storm Water Discharges Associated with Industrial Activities*



facilities, petroleum bulk stations, and lubricating oil blenders and re-refiners), refuse industries, and automobile dismantlers (see Appendix B, Attachment 4). While one would expect these industries to be likely sources of oil and grease due to the nature of their operations, they did not consistently report elevated levels. The occasional spikes may be the result of non-compliance with or the ineffectiveness of best management practices.

It should be noted that certain food-related industries (e.g., pet foods, fruits and vegetables, and animal and marine fats and oils) reported some of the highest concentrations of oil and grease. This probably reflects the fact that the analytical method for oil and grease does not distinguish between biological fats and petroleum-based oils, as discussed earlier.

4.1.3.3 Data considerations

It is important to keep certain considerations in mind in interpreting the industrial NPDES data. The analytical data for oil and grease (and other parameters) are facility-reported concentrations measured from facility-collected discharge samples. In many cases, samples are collected by facility personnel who have variable levels of familiarity with standard methods of sample collection and handling. Additionally, the permit requirements for sample collection allow some degree of flexibility regarding when samples are to be collected. Since pollutant concentrations may be highly variable throughout the course of a storm event as well as from storm-to-storm, the representativeness of a given sample is difficult to ascertain. There may also be variability among the state-certified laboratories in carrying out sample preparation, analytical and other operational procedures.

The statewide oil and grease data are compiled using data submitted by the Regional Boards. While most permitted facilities have been conducting the required monitoring, and complying with the reporting requirement to the Regional Boards, there have been delays in entering the data into databases at the regional level, and in turn, the statewide database. Thus, the database does not include data from all Regional Boards, or for all compliance years. Furthermore, data are entered into both the statewide and the regional databases without a mechanism for quality assurance (SWRCB, 2005a).

4.2 Oil and grease in runoff from urban catchments

One of the factors that influence stormwater quality is land use. Land use monitoring is conducted to characterize stormwater runoff in a drainage area comprised predominantly of a single, relatively homogeneous land use. This generates data that can help evaluate the relative importance of specific land uses as pollution sources (LADPW, 2000).

As mentioned in Section 4.1.1, a study of oil and grease in urban stormwater was conducted during the 1980-81 storm season in a small watershed in Richmond, California (Stenstrom et al., 1984). The purpose of this study was to determine the relationship between land use and oil and grease pollution in urban stormwater. Five sampling stations representing various land uses were monitored over a seven-storm sequence. Samples were analyzed for oil and grease using infrared analysis, a method that has been largely replaced by a gravimetric procedure (Method 1664).

The lowest mean concentration of oil and grease, 3.9 mg/l, was measured at the sampling station draining a primarily residential (95 percent) area; the highest, 16.1 mg/l, at the station located in a commercial department store parking lot. The mean concentration for runoff from a gasoline station, several commercial retail stores and a small residential area had a mean concentration of 10.9 mg/l, while that for runoff collected outside the property limit of a large trucking distribution center (77 percent industrial, 23 percent impervious) was 7.3 mg/l. Runoff at the mouth of the watershed, which represents a composite of all land uses, had a mean concentration of 7.9 mg/l.

As will be discussed below, more recent monitoring studies show lower oil and grease concentrations. One explanation may be that automotive engines tended to leak more lubricating oil in the early 1980's compared to automobiles in more recent years. Another reason may be that the infrared absorption method used in this study has been reported to generally result in higher oil and grease readings when compared to gravimetric analysis. One study reported that infrared analysis yielded at least 20 percent more oil than gravimetric methods from a review of 19 laboratories using both methods (Silverman et al., 1985).

Under a grant from U.S. EPA, a national database of stormwater data from a representative number of NPDES Phase I municipal separate storm sewer system (MS4) permit holders is being developed (Pitt et al., 2004). This database, called the National Stormwater Quality Database (NSQD), includes monitoring data collected from 1990 to 2002 from more than 200 municipalities throughout the country, including two in California (i.e., Alameda County and Caltrans).

As of mid-summer 2003, 3,770 separate events from 66 agencies and municipalities in 17 states have been collected and data entered into the NSQD. The database includes over 1,800 samples tested for oil and grease. Of these, oil and grease were detected in 1,212 samples (66 percent), with concentrations ranging from below detection to 1,100 mg/l, and a median of 4.3 mg/l. The database also reports a mean concentration of 34.5 mg/l, based on detected values only. The oil and grease data are presented graphically in Figure 5. Table 4 summarizes the data by land use categories.

Figure 5. Oil and grease data from the National Stormwater Quality Database

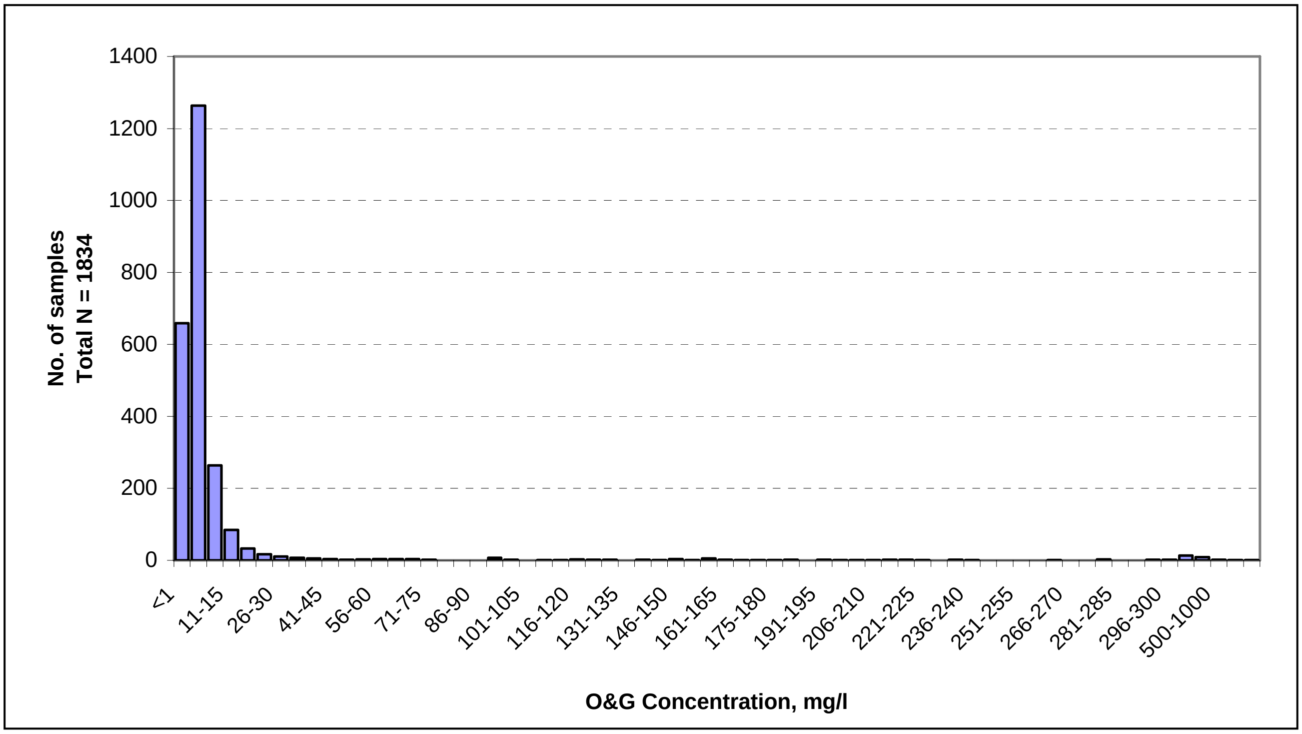


Table 4. Oil and grease concentrations by land use category (as of mid-2003) from the National Stormwater Quality Database

Land use category*	No. of samples	Percent of samples above detection	Median concentration, (mg/l)
Residential	533	58%	3.9
Mixed residential	258	68%	4.4
Commercial	308	71%	4.7
Mixed commercial	122	82%	5.0
Industrial	327	65%	5.0
Mixed industrial	80	78%	4.5
Freeways	60	72%	8.0
Mixed freeways	15	100%	4.0
Open space	19	37%	1.3
Mixed open space	96	63%	6.0
Overall	1,834	66 %	4.3

* Categories that describe “mixed” land uses are designated using the most prominent land use type.

Monitoring of urban catchments in Fresno from 1981 to 1983 (Oltmann, et al., 1987) yielded the highest oil and grease concentrations from runoff draining an industrial area (mean = 10.6 mg/l); concentrations were lowest in runoff from a multiple-dwelling residential area (mean = 1.5 mg/l). Land use monitoring data from Los Angeles (LADPW, 2000) and Ventura (Ventura County, 2001) Counties yielded mean concentrations ranging from 0.9 to 5.7 mg/l. In both counties, commercial land use areas had the highest mean concentrations (see Table 2). Similar values were reported in a study conducted in the City of La Mirada during the 2004/2005 rainy season (La Mirada, 2005), although the highest levels were associated with residential land use. Oil and grease concentrations were measured at 12 street locations with the following results: commercial areas, non-detect (ND) to 2.5 mg/l; residential areas, ND to 3.0 mg/l; and industrial areas, ND to 2.8 mg/l. Commercial areas likewise showed the highest median concentrations of oil and grease in monitoring conducted in Texas (Baird et al., 1996), while levels in areas with other land uses showed more typical median concentrations (between 0.4 to 4.0 mg/l).

Runoff draining industrial areas may also contain relatively higher levels of oil and grease compared to other uses. The Dothan Alabama Stormwater Project (CERS, 2000) characterized runoff from different types of urban and suburban catchments (see Table 2). Samples were collected from 1997 to 1999 from an agricultural field, light industrial site storm drain, a residential subdivision and two commercial parking lots. Mean concentrations of oil and grease were at or below 1.5 mg/l at all the sampling locations, except for the location draining runoff from an area that included a rubber tire manufacturer. Concentrations as high as 50 mg/l were measured at this location. The relatively higher oil and grease levels found at this location may be related to the use of petroleum products at the tire facility.

4.3 Oil and grease in discharges into receiving waters

Mass emissions monitoring is designed to provide data to characterize discharges into receiving waters. More specifically, this type of monitoring enables the derivation of estimated pollutant loads to a receiving waterbody. Mass emissions monitoring stations are located at the lowest point possible in the drainage area where a conveyance discharges storm water to a waterbody, without being affected by tidal influences. Unlike land use monitoring stations, these stations generally monitor runoff from a heterogeneous land use area (LADPW, 2000).

Mass emissions data for monitoring stations in San Diego, Ventura and Los Angeles Counties and the City of Long Beach show that oil and grease concentrations are generally lower than 5 mg/l (San Diego, 2005; Ventura County, 2001; LADPW, 2005; Long Beach, 2005). Further, the levels tend to be lower than those measured at land use monitoring stations and at discrete sources. This is not surprising because mass emission stations capture runoff from a large drainage area; much of the hydrocarbon load may attach to particulates and other matter, and settle out prior to reaching the sampling site. Relatively high levels, however, were reported for the monitoring sites in Long Beach. The City notes that record low rainfall occurred during the 2001-2002 storm season, with total precipitation at 84 percent below normal. The monitored events likely represented seasonal first flush at the monitoring sites, possibly accounting for the high oil and grease concentrations (Long Beach, 2005).

Annual mean concentrations for seven watersheds in Los Angeles County show significant year-to-year variability within watersheds, with one of the watersheds (San Gabriel River) showing over a six-fold difference between its lowest and highest annual mean oil and grease concentrations (see Table 5). For any given year, the difference in annual mean concentrations between individual watersheds can be as high as nine-fold at one extreme, to being almost the same value at the other extreme (i.e., from 2.1 mg/l to 2.5 mg/l for the 2004-05 season). However, when averaged over multiple years for which data were available (as many as ten years for certain watersheds), the resulting values were similar across all the watersheds, regardless of degree of urbanization, the lowest being 1.9 mg/l for San Gabriel River (46 percent undeveloped), the highest, 3.7 mg/l for Ballona Creek (21 percent undeveloped). The reason for this is unclear.

4.4 Ecological and human health considerations

OEHHA performed a screening level analysis to provide a context for interpreting the possible ecological effects associated with the oil and grease concentrations reported in stormwater runoff. The analysis focused on used oil constituents for which numeric aquatic life criteria have been established: arsenic, cadmium, chromium, lead, nickel and zinc (40 CFR 131.38). The highest reported concentrations of these constituents in used oil (OEHHA, 2004) were used to calculate their amounts in runoff containing oil and grease at 5 mg/l (typical concentrations found in the studies reviewed by OEHHA were at or below 5 mg/l). These calculations yielded concentrations of these constituents that were up to five orders of magnitude lower than their respective freshwater and saltwater aquatic life water quality criteria. Nevertheless, these constituents may pose a long-term risk to the aquatic ecosystem because of their tendency to accumulate in sediment over time.

The ecological effects of used oil discharges in stormwater runoff entering receiving water bodies, however, are influenced not only by individual constituents, but also by multiple factors, including the presence of other chemicals, the type and size of the receiving body, the frequency and duration of the discharge, the potential for dispersion, and the biological diversity of the receiving water ecosystem. Complex environmental processes acting on the oil, along with the highly variable nature of the used oil discharge, present a challenge in assessing the impacts of the discharge on the aquatic ecosystem.

Human health impacts will depend upon whether or not exposures to constituents of concern occur from direct contact, ingestion of contaminated water or via the food chain. Studies linking adverse health effects in humans following exposure to used oil contaminants in the aquatic environment were not found.

5.0 Oil and Grease Loading Estimates

Methods and models for estimating the amount of pollutants in runoff range in complexity and data input requirements, from simple algorithms that yield screening-level estimates of storm-specific or seasonal loadings for planning purposes, to highly complex, dynamic models that simulate the movement of precipitation and pollutants to predict flows, stages and pollutant concentrations (Burton and Pitt, 2001).

Modeling fundamentals call for using the simplest model that will satisfy the modeler's objectives (Donigian and Huber, 1991). An objective of this report is to develop a **rough approximation** of the amount of oil in stormwater runoff entering receiving waterbodies.

Table 5. Reported annual mean concentrations for oil and grease in Los Angeles County, 1994-2005

Mass emission site	Annual mean concentration for O&G, in mg/l											Mean O&G concn, all years, in mg/l *(std dev)*
	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	
San Gabriel River		0.68	0.98	0.64	0.81	1.66	2.40	2.83	4.23	2.66	2.50	1.9 *(1.2)*
Coyote Creek*		2.61						3	2.27	2.5	2.5	3 *(0.3)*
Los Angeles River		4.94	2.45	1.38	1.90	2.44	2.86	5.55	4.05	3.10	2.10	3.08 *(1.36)*
Dominguez Channel								3.80	2.30	2.18	2.32	2.65 *(0.77)*
Ballona Creek	2.2	3.0	2.5		7.1	3.5	4.0	5.7	3.8	2.5	2.1	3.6 *(1.6)*
Malibu Creek				2.82	0.95		2.50	2.73	3.83	2.50	2.20	2.5 *(0.86)*
Santa Clara River									2.47	2.22	2.50	2.40 *(0.15)*

*Coyote Creek is the major tributary in the lower reach of the San Gabriel River.

OEHHA has determined that use of the "simple method" (U.S. EPA, 1992b) is adequate to meet this objective. This is one of the methods used in calculating annual pollutant loads for municipal NPDES applications. The same approach is used by Los Angeles County in its annual stormwater monitoring reports (LADPW, 2004a). The simple method has minimal data requirements, does not require specialized computer programs, and is generally deemed adequate for purposes of deriving gross loading estimates for planning purposes.

5.1 Methodology

In the simple method, an estimate of the oil and grease loadings in stormwater runoff entering waterbodies is derived as the product of the concentration of the pollutant [C] and the volume of runoff [R]:

$$L = C \times R$$

When data on runoff volume [R] are not available, R can be calculated using precipitation, the appropriate runoff coefficient, and a correction factor (that adjusts for storms where no runoff occurs). The runoff coefficient represents the percentage of rainfall that becomes surface runoff, and is a function of the imperviousness of the watershed. The runoff coefficient can be based on actual field measurements, relevant hydrologic studies, or default values; alternatively, it can be estimated based on the percent imperviousness of the watershed (U.S. EPA, 1992b).

OEHHA calculated statewide oil and grease loading estimates by first deriving estimated annual loadings for a selected area of the State. The estimated loadings were then used to calculate estimated “unit load” (the estimated mass of pollutant per unit area of a watershed) by dividing the mass loading estimate by the total area in the watershed that is designated as urban. Only urban land areas were used to generate a unit load estimate because oil and grease in runoff is largely associated with urban land uses. Finally, the unit load was multiplied by California’s total urban area to yield a statewide loading estimate. An estimate of the volume of used oil corresponding to the oil and grease mass loading estimates was calculated by dividing the latter by the density of used oil.

5.2 Annual oil and grease mass loading estimates: Los Angeles County

Los Angeles County was selected as the area to be used for deriving mass loading estimates and, subsequently unit load estimates, for a number of reasons:

- Los Angeles County likely represents a worst-case scenario for oil and grease runoff contamination in the State. Its “ultra-urban” watersheds are characterized by high densities of paved surfaces or buildings that result in a high degree of imperviousness. Imperviousness of the watershed is an important determinant of stormwater quality and volume. Three of the watersheds in the county -- Dominguez Channel, Ballona Creek, and Los Angeles River – are about 59 percent, 40 percent and 32 percent impervious, respectively (LADPW, 2005). (See Figure 6 for descriptions of the watersheds.)

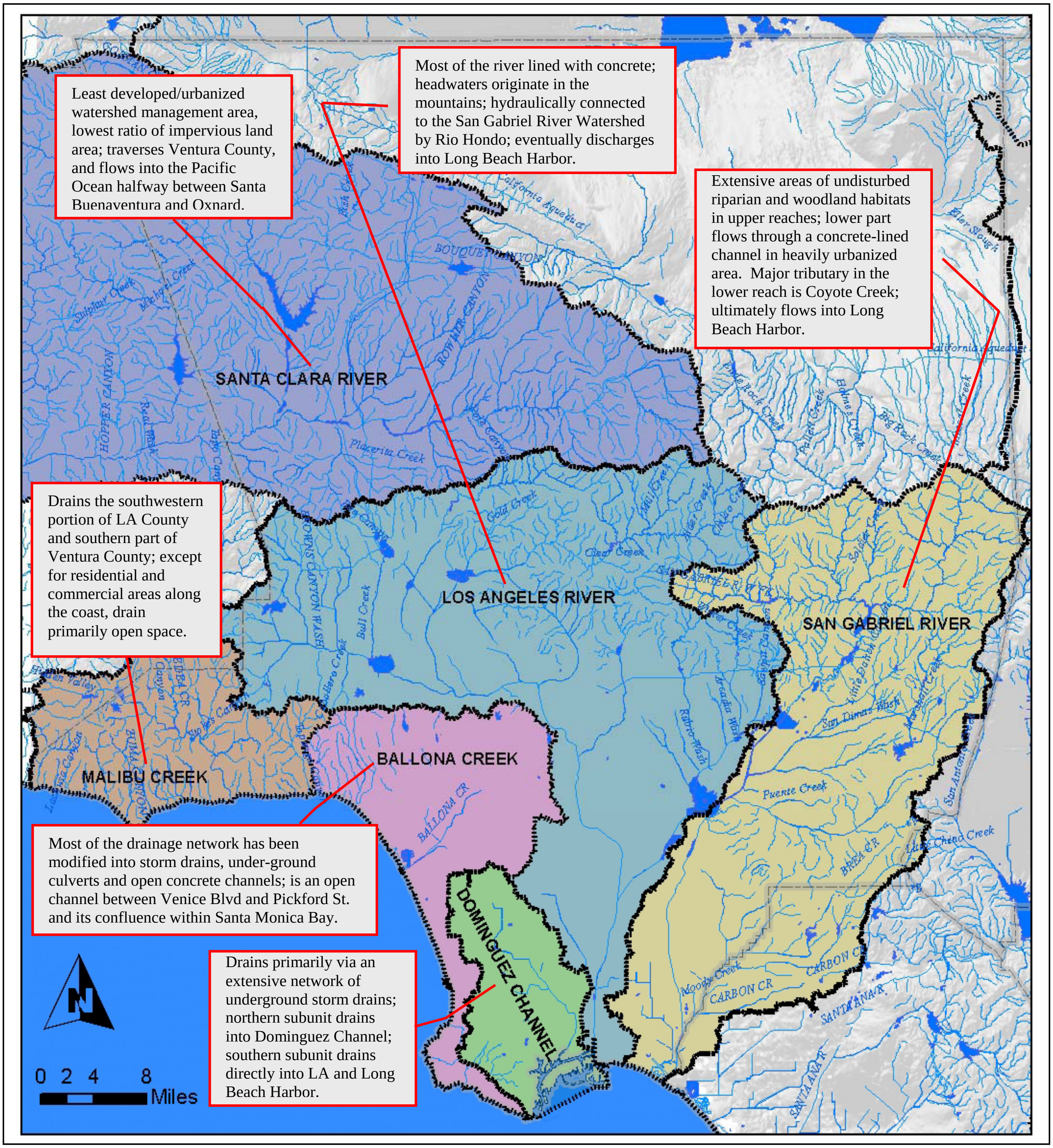
- At the other extreme, the county also includes predominantly undeveloped watersheds: Santa Clara River and Malibu Creek are 7% and 8% impervious, respectively. This enables comparisons to be made between examples representing highly urbanized watersheds and undeveloped watersheds within the same geographic region.

- Los Angeles has the largest population among California’s counties, with 10 million of the State’s approximately 37 million residents; it has the third highest population density, after San Francisco and San Diego Counties.

- In terms of vehicular sources of oil in runoff, Los Angeles County has the most number of registered vehicles (more than 7 million as of December 2003). More than 20% of the State’s 31 million registered vehicles are in Los Angeles County (DOF, 2004b). Additionally, over at least the past five years, the county has had the highest number of vehicle miles traveled over State highways: about 40 billion miles, compared to the Statewide total of 176 billion miles (Caltrans, 2004a).

- Easily accessible data for estimating oil and grease loading are available for the County. At least a decade’s stormwater monitoring data have been reported by the County pursuant to the requirements of its NPDES permit. In addition, several decades of hydrologic data are available.

Figure 6. Los Angeles County's watersheds.



Adapted from: LADPW, 2005; LARWQCB, 2004

5.2.1 Input data

5.2.1.1 Concentration [C]

As was discussed in section 4.3, mass emission monitoring is used to characterize discharges into receiving waters. Mass emission stations monitor relatively large (100 to 1000 square miles) mixed land use watersheds, and are placed at sites that capture stormwater discharges from a conveyance into a waterbody.

Mass emissions monitoring has been conducted by Los Angeles County since the 1994-95 storm season at seven monitoring sites that represent the County's six major watershed areas (see Figure 6). Except for Coyote Creek, which is the major tributary in the lower reach of the San Gabriel River, each of these mass emissions stations represents a major watershed in the County. Average annual mean concentrations for these sites are presented in Table 5 (LADPW, 2005). For each of the watersheds, OEHHA derived the mean of the reported average annual mean concentrations; these values will be used in calculating the loadings estimates.

5.2.1.2. Runoff volume [R]

Six of the seven mass emissions monitoring sites are also the location of stream gaging stations operated by the County. These stations monitor flow or discharge -- i.e., the total volume of water that flows past a point for given period of time (usually measured in cubic feet per second). The County reports total annual runoff volume for each stream gaging station, including six of the seven mass emissions monitoring sites from the late 1920's (LADPW, 2004b). Table 6 presents minimum, maximum and mean runoff volumes for all the years reported, and for the last ten years. Available annual runoff data for Los Angeles County are presented and summarized in Appendix C.

Table 6. Total runoff volume reported for the mass emission/stream gaging stations, Los Angeles County

Station* (Gaging station #)	Years reported	Total Runoff (Acre-feet)					
		All years			Last ten years		
		Minimum	Maximum	Mean (std dev)	Minimum	Maximum	Mean (std dev)
San Gabriel River *(F263C-R)*	1928-2003	558	274,300	53,000 (61,000)	25,720	168,600	57,000 (46,000)
Coyote Creek** *(F354C-R)*	1963-2003	7,950	106,400	41,000 (28,000)	17,758	106,400	53,460 (31,940)
Ballona Creek *(F38C-R)*	1927-2003	3,930	86,347	34,000 (18,000)	26,698	80,630	48,060 (19,320)
Los Angeles River *(F319C-R)*	1928-2003	9,340	1,122,000	180,000 (210,000)	131,061	1,122,000	380,000 (320,000)
Malibu Creek *(F130C-R)*	1930-2003	56	119,900	20,000 (25,000)	7,430	81,700	29,100 (26,600)
Santa Clara River *(F92-R)*	1930-2002	217	83,154	10,000 (20,000)	2,350	53,800	13,200 (14,600)

* No data are available for one of the watershed areas, Dominguez Channel.

It is evident from the table that runoff volumes are highly variable. Given the significant degree of development and urbanization that occurred in the past decade, runoff volumes for the last ten years are likely more representative of current conditions than data for all reporting years; hence, OEHHA used data from the last ten years for its calculations. In order to capture the data variability and provide a reasonable range, OEHHA calculated loading estimates using: (1) the minimum, (2) the maximum, and (3) the average annual runoff volume reported for the last ten years for each monitoring station.

5.2.2 Mass loading calculations

Annual oil and grease loadings were estimated for each watershed using the following formula:

$$L = C \times R$$

Where:

L = Annual estimated oil and grease loading for the watershed;

C = The mean of the reported annual mean concentrations for the watershed (the last column of Table 5); and,

R = Annual runoff volume (minimum, maximum and mean values for the last ten years on Table 6)

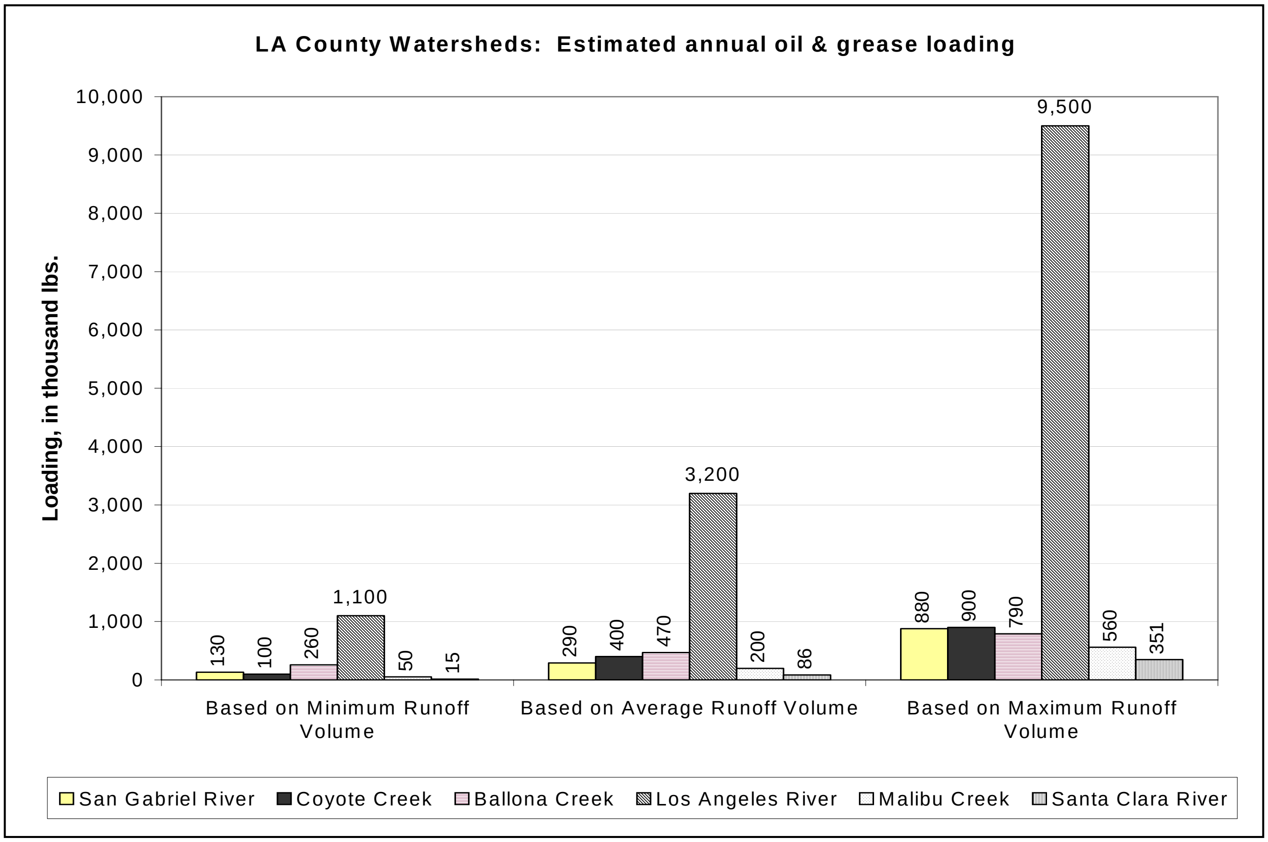
Calculations are provided in Appendix D. Table 7 and Figure 7 present the results of these calculations.

Table 7. Estimated annual oil and grease loadings, Los Angeles County watersheds

Watershed*	Percent impervious area	Average Annual Oil & Grease Concentration (mg/l)	Estimated Annual Oil and Grease Loading (1,000 lbs)		
			Based on Minimum Annual Runoff Volume**	Based on Average Annual Runoff Volume**	Based on Maximum Annual Runoff Volume**
San Gabriel River	29%	1.9	130	290	880
Coyote Creek***	29%	3	100	400	900
Ballona Creek	40%	3.6	260	470	790
Los Angeles River	32%	3.08	1,100	3,200	9,500
Malibu Creek	8%	2.5	50	200	560
Santa Clara River	7%	2.40	15	86	351
Total******			**1,655**	**4,646**	**12,981**

* No estimates were derived for one of the watershed areas, Dominguez Channel.
** From the last ten years of runoff data on Table 6.
*** Coyote Creek is the major tributary in the lower reach of the San Gabriel River.

Figure 7. Estimated annual oil and grease loadings, Los Angeles County watersheds



5.2.3 Estimated volume of used oil in runoff

The approximate volume [V] of used oil corresponding to the mass loading estimate was calculated as follows:

$$V = L/D$$

Where:

L = Estimated oil and grease mass loading;
D = Density of used oil, 0.885 g/ml (Environment Canada, 2005)

The results of the calculations are presented in Table 8; detailed calculations are found in Appendix D. This calculation assumes that the total mass of oil and grease in the loading estimate is made up entirely of used oil. As was discussed in section 3, however, the analytical methods commonly used for oil and grease do not distinguish among various petroleum-based or biological oils, and therefore do not specifically measure used oil.

Table 8. Estimated annual volume of used oil in runoff, Los Angeles County watersheds

Watershed*	Estimated Volume of Used Oil (thousand gallons)		
	Based on Minimum Annual Runoff Volume	Based on Average Annual Runoff Volume	Based on Maximum Annual Runoff Volume
San Gabriel River	18	40	120
Coyote Creek**	20	60	100
Ballona Creek	35	64	110
Los Angeles River	150	430	1,300
Malibu Creek	7	27	75
Santa Clara River	2	12	48
Total	**232**	**633**	**1,753**

* No estimates are presented for one of the watershed areas, Dominguez Channel.
** Coyote Creek is the major tributary in the lower reach of the San Gabriel River.

5.3 Estimated oil and grease loading statewide

To derive a rough approximation of the total amount of oil and grease in runoff statewide, OEHHA used a mathematical approach based on the Los Angeles County mass loading estimates. First, a "unit load" – which is the mass of oil and grease in runoff from a given unit of watershed area -- was calculated by dividing the total estimated mass loading (from Table 7) by the number of urban acres in the County. Since oil and grease in runoff is largely associated with urban areas, only these areas were used in the calculation. The total urban number of acres in Los Angeles County – 503,457 acres -- was determined by adding the acreage for the following land use categories: residential, commercial and public, industrial, transportation and utilities, and mixed use. (The area for the Dominguez Channel watershed was excluded from the calculation since loadings for this watershed are not included in the total estimated loadings for the County.) Three unit load estimates were derived, corresponding to the mass loading estimates based on the minimum, average and maximum runoff volumes for the past ten years.

The statewide loading was then estimated by multiplying the unit load by the total number of urban acres in California, 4,909,000 (CDFFP, 2003). Finally, estimates of the volume of used oil corresponding to the statewide mass loading estimates were calculated using the approach discussed in section 5.2.3. These estimates are presented in Table 9.

Table 9. Estimated annual oil and grease loadings, statewide

	Minimum	Average	Maximum
Total estimated oil and grease mass loading, thousand lbs. (*from Table 7)*	1,655	4,646	12,981
"Unit loading," lbs. per urban acre *(= Total estimated oil and grease mass loading/No. of urban acres in L. A. County)*	3.3	9.2	25
Estimated Statewide mass loading, million lbs *(= Unit loading x No. of urban acres in CA)*	16	45	120
Estimated Statewide loading, million gallons *(Estimated Statewide mass loading/Density of used oil)*	2.2	6.1	16

5.4 Uncertainty analysis

The oil and grease loading estimates represent very rough approximations of the amounts of oil and grease in stormwater. In interpreting the estimates, the following sources of uncertainty should be considered:

- Mass loading estimates were calculated as the product of runoff volume and concentration. Both runoff volume and concentration can exhibit a high degree of year-to-year, inter- and intra-storm variability. To account for the variability in runoff volume, minimum, maximum and average values for ten years' worth of annual runoff data were used. Similarly, an average of the annual mean concentrations available for each watershed was used. The representativeness of the values used in the calculations cannot be ascertained.

- The annual statewide loading estimates are simply mathematical derivations based on the "unit load" for Los Angeles County – i.e., the mass of pollutant per unit urban area per year. Using the County-based unit load Statewide does not account for the widely different types of urban watersheds in the State. In fact, within Los Angeles County, there are considerable differences among the unit load values for the different watersheds, with values ranging from about 2 pounds/acre to almost 20 pounds/acre, for an average runoff year (see Appendix D).

- For purposes of the calculations carried out in this report, the "oil and grease" measured at mass loading stations was assumed to be used oil. Although studies have identified crankcase oil as the predominant hydrocarbon in urban runoff, it cannot be determined what fraction of the mass loading estimate for "oil and grease" can be reasonably assumed to be used oil. Hence, the loading estimate is at best a crude approximation of the amount of used oil in runoff entering receiving waters.

5.5 Comparison with other loading estimates

OEHHA is unable to validate the loading estimates derived in this section. However, it may be useful to consider the estimates within the context of loadings estimates derived by other investigators.

5.5.1 Storm-specific loadings

Los Angeles County's monitoring reports for the 2001-02, 2002-03 and 2003-04 storm seasons include storm-specific loading estimates for certain pollutants, including oil and grease. OEHHA's estimated annual oil and grease loadings for an average annual runoff year (middle column, Table 7) were compared to the County's estimated loadings for the monitored events during the 2002-03 season (see Table 10). The 2002-03 season was chosen for this comparison, as the 2001-02 and 2003-04 seasons were low rainfall years: total seasonal precipitation was 4.2 and 8.4 inches, respectively -- at most about half of the annual average rainfall for the County. By contrast, rainfall for the 2002-03 season was the same as average, 15.5 inches.

Table 10. Oil and grease loadings for monitored events, compared to estimated loadings for average runoff year.

Watershed*	Estimated Average Annual Loading (thousand lbs), (from Table 7)	Total Estimated Loading from LA County monitored events (lbs), 2002-03 Season	Total Estimated Loading from monitored events as % of OEHHA Estimated Average Annual Loading	% of Annual Average Rainfall Monitored
San Gabriel River	290	29,771	10%	40%
Coyote Creek*	400	43,905	10%	57%
Ballona Creek	470	175,984	37%	37%
Los Angeles River	3,200	1,069,043	33%	43%
Malibu Creek	200	12,422	6%	98%
Santa Clara River	86	3,581	4%	10%

As expected, the total loading estimates for all monitored events were below the estimates derived by OEHHA for each watershed, making up from 4 to 37 percent of the latter loadings. The rainfall for the monitored events represented from 10 to 40 percent of the County's annual average rainfall. For two of the watersheds (Ballona Creek and Los Angeles River) pollutant loadings from monitored events were similar to OEHHA's estimated average values.

5.5.2 Oil and grease loading estimates from other studies

Santa Monica Bay

In 1993, a study of pollutant loadings to Santa Monica Bay from stormwater runoff was conducted, primarily for the purpose of identifying catchments with the largest expected contribution of each pollutant (Stenstrom and Strecker, 1993). Oil and grease are among the water quality parameters included in the study. Pollutant loads to the Bay were estimated as the summation of land use-specific loadings. Runoff volumes were calculated based on historical storm data and land use-specific runoff coefficients. Instead of local monitoring data, oil and grease concentrations from an earlier stormwater runoff study conducted in the San Francisco Bay area were used: 0 for open areas; 3 mg/l for single-family land use; and 22 mg/l for all other land uses (multi-family, commercial, public, light industrial, other urban, and unknown).

The study estimated the annual total oil and grease loading into Santa Monica Bay to be **2,110,241** pounds. Of the Los Angeles County watersheds, two drain into Santa Monica Bay: Ballona Creek and Malibu Creek. The sums of OEHHA's loading estimates for these two watersheds range from 310,000 to 1,350,000 pounds, with an average estimate of 670,000 pounds. These estimates are 15 to 64 percent of the estimated loading into Santa Monica Bay from the earlier study. The runoff volumes used in the Santa Monica Bay study (approximately 80,000 acre-feet) were comparable to the values used by OEHHA (approximately 34,000 acre-feet to 160,000 acre-feet, with an average of about 77,000 acre-feet); however, the oil and grease concentrations in the earlier study were six- to eight-fold higher than the values used by OEHHA. It should also be noted that there are other watersheds (in Ventura County) that drain into Santa Monica Bay.

Los Angeles River

Based on monitoring conducted in 1985-86, oil and grease loading to the Los Angeles River was estimated to be 2,900 metric tons or 6,400,000 pounds (SCCWRP, 1986). This falls within the range of OEHHA's estimates for the Los Angeles River of approximately 1,100,000 to 9,500,000 pounds, with an average of 3,200,000 pounds.

6.0 Findings

In this report, OEHHA reviews stormwater monitoring data for the purpose of characterizing used oil pollution in stormwater runoff. Monitoring conducted by municipalities and industrial facilities pursuant to stormwater regulatory programs (more specifically, the National Pollutant Discharge Elimination System or NPDES stormwater program) provided a major source of data relevant to this evaluation. The monitoring conducted under the NPDES program quantifies amounts of "oil and grease," which is collectively regulated as a conventional water pollutant.

Studies have shown that petroleum hydrocarbons in urban runoff from different land use sites were found to be primarily associated with used crankcase oil. Likewise, the type of petroleum hydrocarbons found in sediment in receiving water bodies in urban areas very closely resembles that found in stormwater runoff. Lubricating oils used in industrial processes and in heavy construction equipment are also discharged into stormwater. However, unlike crankcase oil from motor vehicles that generally appears to be discharged continually in small amounts, discharges from industrial facilities tend to occur as localized, sporadic events occasionally involving unusually high levels.

While characterizing pollutant levels in stormwater runoff is an important step in formulating and evaluating mitigation measures, quantifying such levels presents numerous challenges. Concentrations of oil and grease in stormwater runoff are affected by a number of factors, including precipitation, land use, physical characteristics of the watershed, pollutant sources and release mechanisms, and the physical and chemical characteristics of the pollutant. Complex interactions between these factors obscure simple correlations between individual factors and stormwater quality. However, there is evidence that oil and grease concentrations in highway runoff are higher in segments with higher traffic volumes. Further, higher concentrations of oil and grease in highway runoff are generally found to occur during the first storm of the rainy season than subsequent storms, and during the beginning of a rainfall event.

Stormwater runoff in urban watersheds transports pollutants from discrete sources (e.g., highways, parking lots, industrial facilities) and diffuse catchment areas, through conveyances that ultimately discharge into receiving water bodies. Direct comparisons among the oil and grease concentrations reported by the studies reviewed in this report (see Table 2) are problematic due to differences in sampling protocols, analytical methods (including different detection limits for the same method, depending on the laboratory), quality assurance/quality control processes, and data analysis and reporting procedures employed. Nevertheless, qualitative conclusions can be drawn about relative patterns that are evident from the data. In general, oil and grease concentrations tend to be higher in runoff sampled from discrete sources before dilution, partitioning, adherence to particulates, settling, and other fate processes occur. Relatively lower concentrations are typically found in samples collected to represent runoff in catchment areas with a predominant land use, and even lower levels in samples from discharges into a receiving water body.

While stormwater quality can show considerable variability, typical concentrations of oil and grease in runoff samples are generally less than 5 mg/l, and seldom exceed 10 mg/l. Although petroleum product concentrations as low as 1 microgram per liter have been associated with long-term sublethal effects in aquatic organisms, no human or ecological health-based numeric regulatory standard has been adopted for oil and grease in stormwater discharges. Rather, water quality regulations specify that the pollutant should not be present at levels that produce a visible oily sheen. Establishing numeric water quality criteria for oil and grease is made difficult by the myriad of organic compounds with varying physical, chemical and toxicological properties that make up their constituents. For stormwater discharges from industrial facilities, a concentration of

15 mg/l is generally used as a benchmark that may trigger further actions, such as inspections by the Regional Water Quality Control Board, or changes to best management practices.

Areas that experience a high volume of vehicular traffic, such as highways, parking lots and gasoline stations are commonly thought of as discrete sources of oil and grease in runoff, as are certain industrial facilities with operations that involve petroleum products. However, runoff from these sources follow the same pattern seen with the overall data, i.e., oil and grease concentrations generally at or below 5 mg/l. Although the median concentration reported by industrial facilities statewide is 5 mg/l, the mean concentrations ranged from 11.2 to 12.5 mg/l. Occasionally, unusually high levels have been reported: for highways and parking lots, levels above 10 mg/l are considered high; for industrial facilities, levels as high as 33,000 mg/l have been reported (in more recent years, maximum values have been up to 1,800 mg/l). An oil and grease concentration as high as 1,800 mg/l would likely contain metals at levels below current aquatic life water quality criteria; however, the criteria for cadmium, lead and zinc will likely be exceeded at oil and grease concentrations of 33,000 mg/l. It should be noted, however, that these elevated concentrations were measured close to, or at the source; concentrations in the runoff entering the closest receiving water body are likely to contain oil and grease at lower concentrations.

Industries whose operations involve vehicles, heavy equipment and engines, and petroleum product processing or use tend to report high concentrations of oil and grease in stormwater runoff. These include transportation facilities, petroleum bulk stations, and lubricating oil blenders and re-refiners, refuse industries, metal fabricators, and automobile dismantlers. Even with these industries, however, oil and grease concentrations show sporadic spikes, rather than consistently high levels. The occasional spikes may be the result of non-compliance with, or the ineffectiveness of best management practices. Generally, simple measures such as using spill response kits and drip pans, and covering equipment and other sources of oil and grease can effectively reduce releases. Hence, industrial facilities may present key opportunities for major reductions of oil and grease discharges in stormwater runoff.

Monitoring conducted to characterize runoff from catchment areas having a predominant land use indicates that oil and grease concentrations tend to be higher at sites associated with commercial land use (i.e. retail and office buildings) than with other land uses. Mean concentrations as high as 13 mg/l have been reported for commercial areas. The lowest concentrations were associated with agricultural land use (0 to 0.9 mg/l). Mean concentrations associated with residential land use ranged from 1.0 to 4.7 mg/l.

Mass emissions monitoring, typically at outfalls to a receiving water body, is designed to characterize concentrations from a relatively large drainage area. It also provides data for estimating pollutant loadings. Monitoring by municipalities in Southern California generally yielded mass emissions concentrations below 5 mg/l. Annual mean oil and grease concentrations reported for the seven watersheds in Los Angeles County showed significant year-to-year variability within each watershed. The annual mean concentrations among the watersheds, which included ultra-urban as well as relatively undeveloped ones, showed almost a nine-fold difference during one year (1998-99), to being practically the same value another year. Interestingly, however, when averaged over multiple years (as many as ten years for certain watersheds), the resulting values were similar across all the watersheds, regardless of degree of urbanization.

Finally, oil and grease concentrations reported in earlier studies (from around the 1980s to early 1990s) tended to be higher than in more recent studies. A possible explanation for this may be that less crankcase oil has been leaking from more recent years' vehicle fleets.

Los Angeles County was used as a case study for deriving crude estimates of annual oil and grease loadings, or the amount of oil and grease discharged into receiving water bodies each year. The County likely represents a worst-case scenario because of its "ultra-urban" watersheds, its large population (the largest among California's counties), and its number of vehicles and vehicle miles traveled, also the highest among all counties. At the same time, the presence of predominantly undeveloped watersheds in the same county alongside the highly urbanized ones enables comparisons to be made. Runoff and mass emissions data required to calculate oil and grease loadings were easily accessible for the County.

A simple, screening level calculation was used to derive the annual loadings estimates as the product of pollutant concentration and runoff volume. Oil and grease loadings were estimated to range from approximately 1.7 million pounds to 13 million pounds annually for Los Angeles County. These values correspond to approximately 0.23 million to 1.8 million gallons of used oil. Using these estimated values, total loadings statewide were derived mathematically to range from 16 million to 120 million pounds, an amount roughly corresponding to 2.2 million to 16 million gallons of used oil, respectively, with 6.1 million gallons as the estimated volume for an average runoff year. These volumes are about 3 to 25 percent of the 64 million gallons of lubricating oil sold but not recycled, and about 1 to 9 percent of the 176 million gallons of lubricating and industrial oil sold but not recycled.

It is difficult to establish the ecological and human health implications of the typical concentrations reported in runoff and the loading estimates for oil and grease. A screening level analysis performed by OEHHA showed that, at an oil and grease concentration of 5 mg/l (typical concentrations found in the studies reviewed by OEHHA were at or below 5 mg/l), used oil constituents for which water quality aquatic life criteria have been established --- arsenic, cadmium, chromium, lead and zinc (40 CFR 131.38) – are likely to occur at concentrations up to five orders of magnitude lower than freshwater and saltwater aquatic life water quality criteria. Nevertheless, these constituents may pose a long-term risk to the aquatic ecosystem because of their tendency to accumulate in sediment over time.

The ecological effects of used oil discharges in stormwater runoff entering receiving water bodies are influenced not only by individual constituents, but also by multiple factors, including the presence of other chemicals, the type and size of the receiving body, the frequency and duration of the discharge, the potential for dispersion, and the biological diversity of the receiving water ecosystem. Complex environmental processes acting on the oil, along with the highly variable nature of the used oil discharge, present a challenge in assessing the impacts of the discharge on the aquatic ecosystem.

Human health impacts will depend upon whether or not exposures to constituents of concern occur from direct contact, ingestion of contaminated water or via the food chain. Studies linking adverse health effects in humans following exposure to used oil contaminants in the aquatic environment were not found.

The relationship between the estimated loadings and the amount of used oil that is illegally disposed of cannot be established. Used oil in stormwater runoff can primarily be attributed to leaks and spills from vehicle engines or from industrial activities. It is unlikely that that this amount reflects how much used oil is illegally disposed, given the episodic nature of illegal disposal incidents.

OEHHA is unable to ascertain how close these estimates are to actual amounts of used oil in runoff being discharged into receiving water bodies. There is considerable uncertainty in the estimate, given limitations relating to how close the concentrations in the samples represent actual concentrations of the pollutant, the inability of the commonly used analytical method to distinguish between petroleum-based hydrocarbons and biological lipids, and the appropriateness of extrapolating statewide loadings from estimates derived for a single county. In the absence of a more refined analysis, however, these estimates can be used as a baseline for planning and mitigation purposes.

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APPENDIX A
Stormwater Runoff: Regulatory Background

Under the Clean Water Act, all facilities discharging pollutants from any point source into waters of the United States are regulated under the National Pollutant Discharge Elimination System (NPDES). At the onset of the NPDES Program in the early 1970s, the focus was primarily on reducing pollutants in discharges of industrial process wastewater and municipal sewage. However, as pollution controls were implemented for these sources, it became evident that more diffuse sources, including urban runoff, were also major causes of water quality problems. As a result, the 1987 amendments to the Clean Water Act specified that certain stormwater discharges – which are generally discharged through conveyances such as separate stormwater sewage systems -- are point sources that are subject to NPDES permit requirements (U.S. EPA, 1990). NPDES regulations are promulgated by the U.S. Environmental Protection Agency. In California, the NPDES Program is administered by the State Water Resources Control Board and the nine Regional Water Quality Control Boards (SWRCB, 2005a, b).

The NPDES stormwater permit regulations cover stormwater discharges from:

- **municipal separate storm sewer systems (MS4s)** in urbanized areas;
- **industrial facilities** in any of the eleven categories that discharge to an MS4 or to waters of the United States; and,
- **construction** activity that disturbs land areas of one or more acres.
  (U.S. EPA, 2003)

Municipal separate storm sewer system (MS4) permits

A municipal separate storm sewer (MS4) is a conveyance or system of conveyances, (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) designed for collecting and conveying stormwater, which is not a combined sewer nor part of a publicly owned treatment works, and which is owned or operated by a state or local government entity (40 Code of Federal Regulations, Section 122.26(b)(8)).

The MS4 permits require the discharger to develop and implement a Storm Water Management Plan with the goal of reducing the discharge of pollutants to the maximum extent practicable. The management programs specify what best management practices (BMPs) will be used to address certain program areas. The program areas include public education and outreach; illicit discharge detection and elimination; construction and post-construction; and good housekeeping for municipal operations. In general, medium and large municipalities are required to conduct chemical monitoring, though small municipalities are not (SWRCB, 2005a). Storm Water Management Plans generally include provisions for reducing the amounts of oil in stormwater. For example, municipalities promote used oil recycling, proper management of used oil at municipal facilities and minimization of oil buildup on streets and parking areas within the control of the jurisdiction (City of Santa Rosa/County of Sonoma/Sonoma County Water Agency, 2004).

Caltrans MS4 permit

Caltrans is subject to an NPDES permit in those areas of the State requiring an MS4 storm water permit. A statewide permit has been issued to enable Caltrans to implement a uniform stormwater program. This permit covers stormwater discharges from all Caltrans highways, properties, activities and facilities throughout the State, and stormwater discharges associated with construction activity including clearing, grading, and excavation (SWRCB, 1999).

As with other MS4 permittees, Caltrans must implement a Stormwater Management Plan to reduce or prevent pollutants in stormwater discharges and authorized non-stormwater discharges. The permit also addresses requirements for training and public education, and program evaluation and monitoring.

Industrial permits

In order to minimize the impact of stormwater discharges from industrial facilities, the NPDES program includes an industrial stormwater permitting component. Operators of industrial facilities included in one of the 11 categories of stormwater discharges associated with industrial activity that discharge or have the potential to discharge stormwater to an MS4 or directly to receiving waters require an NPDES industrial stormwater permit. (Construction activity is one of these 11 categories, but is covered under a separate type of permit because of the significantly different nature of its operations.) (U.S. EPA, 2005b)

Industrial stormwater permits require the implementation of management measures that will achieve the performance standard of best available technology economically achievable and best conventional pollutant control technology. Permittees are also required to develop a stormwater pollution prevention plan designed to identify sources of pollutants and ways to reduce storm water pollution from these sources, and a monitoring plan (SWRCB, 2005b).

Industrial facilities in municipalities with an MS4 NPDES permit may be subject not only to the requirements of their stormwater permit, but also to local ordinances that address the discharge of pollutants into the MS4. Further, certain industries that are not required to obtain a NPDES stormwater permit, such as retail gasoline outlets, may be covered by stormwater-related provisions of a local ordinance pursuant to the latter’s stormwater management pollution prevention plan.

Construction permits

Dischargers whose projects disturb one or more acres of soil or whose projects disturb less than one acre but are part of a common plan of development involving one or more acres, are required to obtain coverage under the General Permit for Discharges of Storm Water Associated with Construction Activity. Construction activities subject to this permit include clearing, grading and disturbances to the ground such as stockpiling, or excavation. Regular maintenance activities performed to restore the original line, grade, or capacity of a facility are not covered.

The Construction General Permit requires the development and implementation of a Storm Water Pollution Prevention Plan (SWPPP), which describes, among other things, BMPs the discharger will use to protect storm water runoff and visual, chemical and sediment monitoring programs (U.S. EPA, 2005).

References:

City of Santa Rosa/County of Sonoma/Sonoma County Water Agency, *MS4 NPDES Term 2, Annual Report 1, July 1, 2003-June 30, 2004.* October 1, 2004. Posted at: http://ci.santa-rosa.ca.us/pworks/other/SW/AnnRepSep30.pdf

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APPENDIX B
California Industrial Stormwater Discharges

Background

Stormwater discharges from certain industrial facilities are subject to the requirements of a permit under the NPDES Program. Eleven categories of facilities are subject to this requirement, including: mining/oil and gas facilities; hazardous waste treatment, storage or disposal facilities; recycling facilities (such as metal scrap yards, battery reclaimers, salvage yards, and automobile dismantlers); transportation facilities that conduct any type of vehicle maintenance (such as fueling, cleaning, and repairing); and certain "light industries" where industrial materials, equipment or activities are exposed to stormwater (SWRCB, 1997).

For the most part, these regulated facilities are identified in federal regulations by Standard Industrial Classification (SIC) Codes. SIC codes represent a category within the Standard Industrial Classification System administered by the U.S. government. The system uses a two-digit code designating major industry groups, which is coupled with a second two-digit code representing subcategories. Definitions of SIC codes found to have high oil and grease releases can be found in Attachment 1 of this appendix.

California's nine Regional Water Quality Control Boards administer the industrial stormwater NPDES Program. There are over 7,000 industrial facility permittees in the state. The following table shows the number of active permits by region (SWRCB, 2005a).

Approximate number of active permitted industrial NPDES stormwater facilities in 2005

Region	Region name	Approximate number of active sites
1	Northwest Coast	356
2	San Francisco Bay	1393
3	Central Coast	396
4	Los Angeles	2812
5	Central Valley	
5R	*Redding*	174
5S	*Sacramento*	1134
5F	*Fresno*	593
6	Lahontan	
6A	*South Lake Tahoe*	34
6B	*Victorville*	165
7	Colorado River Basin	166
8	Santa Ana	1486
9	San Diego	699

Regulatory requirements

Major requirements of industrial NPDES permits include the following:

Discharge limitations. Stormwater discharges are required to meet all applicable effluent limitations. Where numeric effluent limitations have not been established, facilities must implement best management practices (BMPs) to control pollutant discharges in stormwater. The Regional Boards in most instances have adopted the U.S. EPA's oil and grease benchmark number of 15 mg/l, although benchmarks of 10, 20 and 40 mg/l have been used. These benchmarks are not necessarily protective of any specific receiving water, and exceedances of these benchmarks are not automatically considered permit violations. When benchmarks are exceeded, inspections by Regional Board staff may be triggered, and/or facilities may be required to re-evaluate the effectiveness of their BMPs and develop, when appropriate, additional BMPs (SWRCB, 1997; RWQCB).

Stormwater Pollution Prevention Plan (SWPPP). Permittees must develop and implement a SWPPP. The objectives of the SWPPP are two-fold: (1) to identify and evaluate sources of pollutants associated with industrial activities that may affect the quality of stormwater discharges and authorized non-storm water discharges from the facility; and (2) to identify and implement site-specific BMPs to reduce or present pollutants associated with industrial activities in storm water discharges and authorized non-storm water discharges. BMPs are generally categorized as non-structural (e.g., good housekeeping, preventive maintenance, spill response, material handling and storage, employee training, and waste handling or recycling) and structural (e.g., treatment measures, runoff control devices, secondary containment structures, and overhead coverage). Non-stormwater discharges include waters from the rinsing or washing of vehicles, equipment, buildings, or pavement; materials that have been improperly disposed, or spilled or leaked materials.

Monitoring program. Among other things, monitoring is used to assist in the implementation of the SWPPP and to measure the effectiveness of BMPs.

Annual report. Each regulated facility must submit an Annual Report to their Regional Board by July 1 of each year. The report includes a summary and an analysis of visual observations and sampling results, and an explanation of why a facility did not implement any activities required by the permit. Laboratory analytical reports are submitted as part of the annual report. The annual reports are the sources of the data presented in this report.

Data considerations

Sample collection and analysis. Stormwater samples are generally collected by facility personnel from locations on the property as identified in the SWPPP. The NPDES permit requires that samples be collected during the first hour of discharge from the first storm of the wet season and at least one other storm; both storms should have been preceded by three working days without stormwater discharge. Sampling is conducted only during scheduled facility operating hours, and need not occur during adverse climatic conditions. Thus, required sampling conditions may not be met, as specified by the permit. Samples must be analyzed by state certified laboratories for pH, specific conductance, total suspended solids and total organic carbon. Oil and grease may be substituted for the total organic carbon.

Database characteristics. The database was created by the State Water Resources Control Board by collecting and merging all available Regional Board electronic annual report data into one table (in Microsoft Access) (SWRCB, 2005b). The database includes the facility identification number, SIC code, the Regional Board with jurisdiction over the facility, fiscal year for which the report is submitted, and reported analytical results. The database used for this report included almost 30,000 entries, covering data from the 1993-94 through 2003-04 reporting years.

Data Limitations. It is important to keep certain considerations in mind in interpreting the industrial NPDES data. The analytical data for oil and grease (and other parameters) are facility-reported concentrations measured from facility-collected discharge samples. In most cases, samples are collected by facility personnel with variable levels of training and familiarity with sample collection and storage requirements and protocol. Permit requirements allow some degree of flexibility in when samples are to be collected. Since pollutant concentrations may be highly variable throughout the course of a storm event as well as from storm-to-storm, the representativeness of a given sample is difficult, if not impossible, to ascertain. There may also be variability among the state-certified laboratories in carrying out sample analysis.

With regard to the database, the statewide oil and grease (and other parameter) data are compiled using data submitted by the Regional Boards, with little quality assurance. The database does not include data from all Regional Boards, or for all compliance years. While most permitted facilities have been conducting the required sampling and monitoring, as well as complying with the annual reporting requirement to the Regional Boards, there have been delays in entering the data into an electronic database at the regional level, and in turn, the statewide database.

Statewide summary

A summary of the data reported statewide for oil and grease for the 2000-2001 to 2002-2003 reporting years can be found in the following table. For these years, the data are predominantly from the San Francisco Bay, Central Coast, Los Angeles, and Santa Ana Regions.

Summary of oil and grease data from *Annual Report for Storm Water Discharges Associated with Industrial Activities*

	Reporting Year*		
	2000-2001	2001-2002	2002-2003
Number of oil and grease (O&G) samples	5192	4987	4778
Percent detect	80%	80%	76%
Percent of O&G samples $\geq$ 15 mg/l benchmark value	16%	16%	17%
O&G concentrations, mg/l			
Minimum	0	0	0
Maximum	1640	1802	1664
Mean including non-detects, mg/l (Standard deviation)	11.2 (39.8)	13.7 (60.8)	12.5 (55.2)
Mean without non-detects, mg/l (Standard deviation)	13.8 (43.9)	17.2 (67.7)	16.4 (62.9)
Median, mg/l	5	5	5
Mode	5	5	5

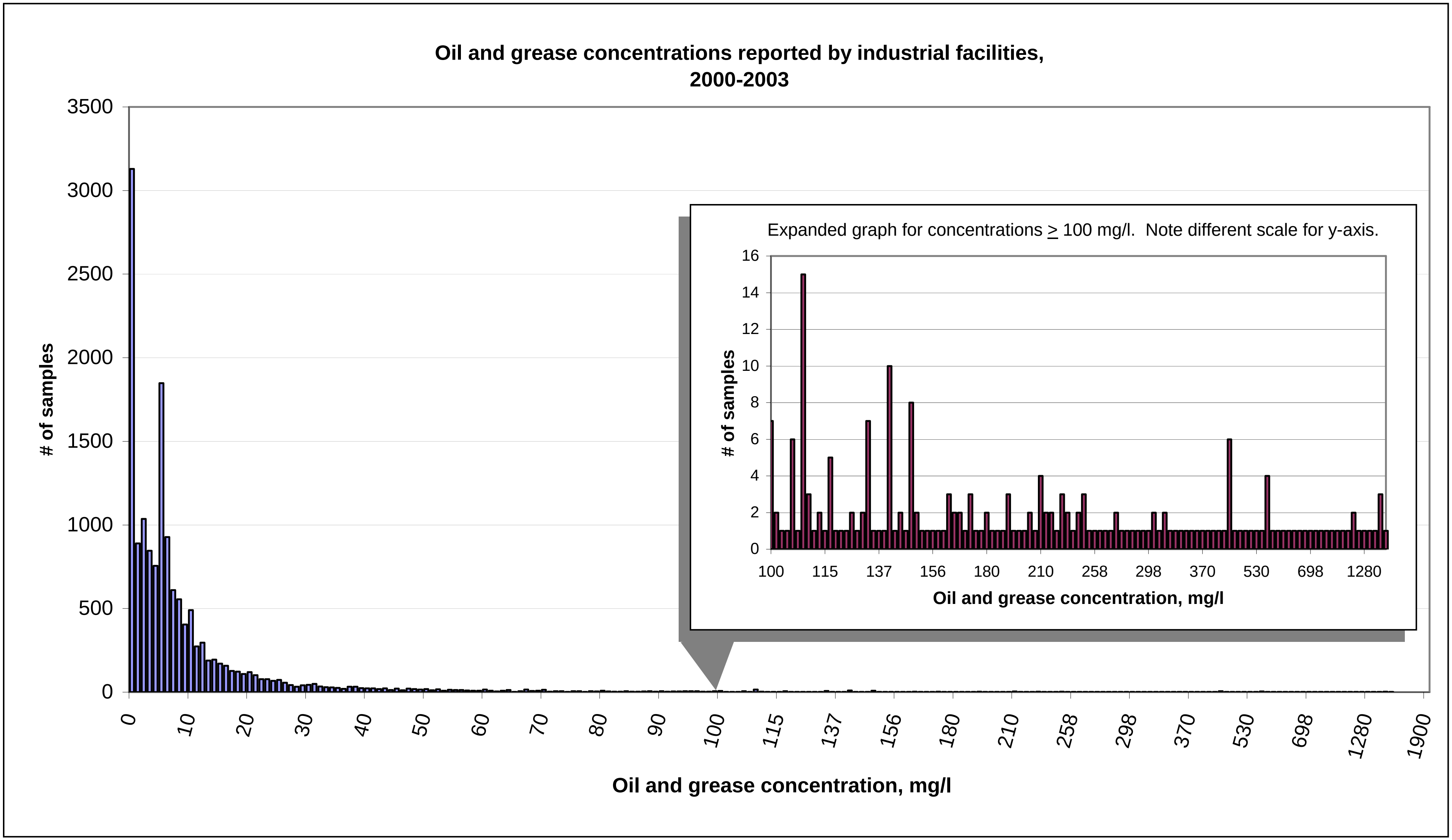
* The number of reports in the database for the years prior to 2000-01 and for 2003-2004, was significantly less than the years included in the table.

As shown in the above table, oil and grease was detected in 76 to 80 percent of the samples; of these, about 16 percent exceeded the benchmark concentration of 15 mg/l. The most frequently reported concentrations were 0 and 5 mg/l. While the database does not provide information about the analytical detection limits for the samples, it is likely that the high frequency of 5 mg/l may be a reporting artifact because this concentration is generally the limit of detection for the method used for oil and grease analysis (U.S. EPA, 2000b).

Attachment 2 presents summaries of oil and grease data for selected Regional Boards. The data appear to indicate that the more highly urbanized regions -- i.e., Los Angeles, Santa Ana, and San Francisco Bay -- have a higher proportion of samples above the benchmark than the more rural Central Coast.

Although about 85 percent of all the samples had concentrations at or below 10 mg/l, significantly higher concentrations (over 100 mg/l) are occasionally reported. As shown on the above table and the graph below, maximum concentrations can exceed 1,000 mg/l. Prior to the 2000-2001 reporting year, even higher oil and grease concentrations (e.g., 33,200 mg/l) were found; however, such large spikes have not been reported since.

Oil and grease data from *Annual Report for Storm Water Discharges Associated with Industrial Activities* (SWRCB, 2005b)



These data are consistent with results of studies conducted elsewhere. For example, in an Alabama storm water runoff study (CERS, 2000), the concentrations of oil and grease from different types of urban and suburban catchments were studied over seven to ten rain events. A site from each of the following types was monitored: agricultural, residential, light industrial, light to moderate parking, and a heavily used mall parking lot. Generally, all the sites had concentrations ranging from less than 1 to 3 mg/l. The exception to this was the storm drain from the light industrial site, which had sporadic concentrations as follows: 50.4, 2.46, 3.4, 1.5, 26.5, 2.4, 1.0, 1.5, 1.0, and 6.6 mg/l.

Industries that tend to have high concentrations of oil and grease

To identify industries that may be releasing the highest concentrations of oil and grease, samples with concentrations of 400 mg/l and higher were identified from the statewide database for all reporting years. Oil and grease data for the industry categories reporting these elevated concentrations were analyzed. While one would expect these industries to be likely sources of oil and grease due to the nature of their operations, they did not consistently report elevated levels. The occasional spikes may be the result of non-compliance with, or the ineffectiveness of best management practices. (See Attachment 1 for a description of the industry categories.)

Only about 0.5 percent of the almost 12,000 oil and grease samples were at or above 400 mg/l. The industry categories in this group include those that use or process petroleum products (e.g., transportation facilities, petroleum bulk stations, and lubricating oil blenders and re-refiners), refuse industries, and automobile dismantlers (see Attachment 3).

It should be noted that certain food-related industries (e.g., pet foods, fruits and vegetables, and animal and marine fats and oils) reported some of the highest concentrations of oil and grease. This reflects the fact that the analytical method for oil and grease does not distinguish between biological fats and petroleum-based oils, as discussed in section 3.3 of this report.

An evaluation of both the statewide and regional data (from four regions) for these industries revealed that some industries had repeatedly high oil and grease concentrations. Maximum values, as well as descriptors of central tendency (i.e., mean and median) consistently ranked highest for the following industry categories (see Attachment 4 for further information):

- Lubricating oils and greases
- Petroleum bulk stations
- Bus charter service, except local
- Refuse systems (garbage)
- Scrap and waste materials (salvage yards)
- Local trucking, with storage

- Railroads, line-haul operating
- Concrete products, except block & brick
- Terminal/service facilities for motor vehicle passenger transportation
- Metal stampings
- Adhesives and sealants
- Pumps and pumping equipment
- Fabricated metal products
- Motor vehicle parts, used

References

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APPENDIX B: ATTACHMENT 1

Standard Industrial Codes (SIC) Definitions for Industries Reporting High Concentrations of Oil and Grease in Stormwater

2891 Adhesives
Establishments primarily engaged in manufacturing industrial and household adhesives, glues, caulking compounds, sealants, and linoleum, tile, and rubber cements from vegetable, animal, or synthetic plastics materials, purchased or produced in the same establishment. Does not include the manufacture of gelatin or agar-agar.

2992 Lubricating Oils and Greases
Establishments primarily engaged in blending, compounding, and re-refining lubricating oils and greases from purchased mineral, animal, and vegetable materials. Examples of lubricating oils and greases are lubricating and cutting oils, greases, brake, hydraulic, and transmission fluids, and rust arresting compounds, and animal and vegetable oil base. Petroleum refineries engaged in the production of lubricating oils and greases are classified in Industry 2911.

3272 Concrete Products, except Block and Brick
Establishments primarily engaged in manufacturing concrete products, except brick, from a combination of cement and aggregate. Contractors engaged in concrete construction work are classified in Division C, Construction, and establishments primarily engaged in mixing and delivering ready-mixed concrete are classified in Industry 3273. Some examples of concrete products from this SIC are: art marble, cast stone, concrete bathtubs, burial vaults, ceiling squares, culvert pipes, drain tiles, concrete fireplaces, and floor tiles.

3469 Metal Stampings
Establishments primarily engaged in manufacturing metal stampings and spun products, including porcelain enameled products. Products of this industry include household appliance housings and parts; cooking and kitchen utensils; and other non-automotive job stampings. Some products examples of this category are: appliance parts, ashcans, license tags, bottle openers, garbage cans, furniture, lunch boxes, machine parts, mail boxes, pails, pans, and patterns on metal.

3499 Fabricated Metal Products
Establishments primarily engaged in manufacturing fabricated metal products such as fire or burglary resistive steel safes and vaults; collapsible tubes of thin flexible metal. Also included are metal boxes, ladders, household articles, ice cream freezers, ironing boards, automobile seat frames, ammunition boxes, aerosol values, furniture parts, and locks.
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3561 Pumps and Pumping Equipment
Establishments primarily engaged in manufacturing pumps and pumping equipment for general industrial, commercial, or household use, except fluid power pumps and motors.

Included are establishments primarily engaged in manufacturing domestic water and sump pumps. Also, oil well pump and oil field pumps.

<u>4011 Railroads, Line-Haul Operating</u>
Establishments primarily engaged in line-haul railroad passenger and freight operations. Included are electric and interurban railways. Railways primarily engaged in furnishing passenger transportation confined principally to a single municipality, contiguous municipalities, or a municipality and its suburban areas are classified in Major Group 41.

<u>4142 Bus Charter Service, Except Local</u>
Establishments primarily engaged in furnishing bus charter service, except local, where such operations are principally outside a single municipality, outside one group of contiguous municipalities, and outside a single municipality and its suburban areas.

<u>4173 Terminal and Service Facilities for Motor Vehicle Passenger Transportation</u>
Establishments primarily engaged in the operation of motor vehicle passenger terminals and of maintenance and service facilities, not operated by companies that also furnish motor vehicle passenger transportation. Some examples are: bus terminals and maintenance facilities.

<u>4212 Local Trucking, without Storage</u>
Establishments primarily engaged in furnishing trucking or transfer services without storage for freight generally weighing more than 100 pounds, in a single municipality, contiguous municipalities, or a municipality and its suburban areas. Establishments primarily engaged in furnishing local courier services for letters, parcels, and packages generally weighing less than 100 pounds are classified in Industry 4215. Some examples of this category are: baggage transfer, carting by horse drawn wagon or hauling animals, debris removal, furniture moving, garbage collecting and hauling by dump truck, log and timber trucking, rental of trucks with drivers, star routes, and mail carriers.

<u>4953 Refuse Systems</u>
Establishments primarily engaged in the collection and disposal of refuse by processing or destruction or in the operation of incinerators, waste treatment plants, landfills, or other sites for disposal of such materials. Included are the collection and disposal of acid waste, ashes, garbage, rubbish, sludge, radioactive waste materials, and street refuse; operation of dumps, hazardous waste material disposal sites, incineration, sanitary landfills, refuse systems; and waste disposal at sea. Establishments primarily engaged in collecting and transporting refuse without such disposal are classified in Transportation, Industry 4212.

<u>5015 Motor Vehicle Parts, Used</u>
Establishments primarily engaged in the distribution at wholesale or retail of used motor vehicle parts. This industry includes establishments primarily engaged in dismantling motor vehicles for the purpose of selling parts.

5093 Scrap and Waste Materials
Establishments primarily engaged in assembling, breaking up, sorting, and wholesale distribution of scrap and waste materials. This industry includes auto wreckers engaged in dismantling automobiles for scrap. Also are automotive wrecking, bottles, fur cuttings, metal, iron and steel, junk and scrap, oil, plastics, rags, textiles, rubber, and wastepaper waste wholesale. Establishments engaged in dismantling cars for the purpose of selling secondhand parts are classified in Industry 5015.

5171 Petroleum Bulk Stations
Establishments primarily engaged in the wholesale distribution of crude petroleum and petroleum products, including liquefied petroleum gas, from bulk liquid storage facilities.

***Reference**:*
U.S. Department of Labor, Occupational Safety & Health Administration, *SIC Division Structure*. Posted at: http://www.osha.gov/pls/imis/sic_manual.html

APPENDIX B: ATTACHMENT 2

Summary of Oil and Grease (O&G) Data from *Annual Reports for Storm Water Discharges Associated with Industrial Activities* for Selected Regional Boards

Region 2, San Francisco Bay Regional Water Quality Control Board
(Reporting years 2001 to 2003)

	2001-2002	2002-2003	2003-2004
No. of oil and grease samples	1,718	1,696	1,548
Oil and grease concentration, mg/l			
Minimum	0	0	0
Maximum	1100	1490	880
Mean (Standard deviation)	17.5 (69.7)	22.8 (107.1)	18.4 (61.3)
Median without zeros	5.6	6.2	7.0
Median counting zeros	2.6	1.0	1.0
Number of O&G samples with concentrations ≥ 15 mg/l	118	118	111
Percent of samples ≥ 15 mg/l	11 %	11 %	12 %

Region 3, Central Coast Regional Water Quality Control Board
(Reporting years 1999 to 2004)

	1999 - 2000	2000 - 2001	2001 - 2002	2002 - 2003	2003 - 2004	2004-2005
No. of oil and grease samples	350	538	378	352	512	684
Oil and grease concentration, mg/l						
Minimum	0	0	0	0.14	0	0
Maximum	1640	835	360	920 *	220	180
Mean (Standard deviation)	27.7 (157.9)	12.2 (53.7)	9.0 (24.1)	20.0 (84.4)	14.5 (27.3)	2.5 (8.1)
Median without zeros	7	5.0	5.0	NA	0	5.8
Median counting zeros	1.2	5	5	6.6	7	0
Number of O&G samples with concentrations > 15 mg/l	18	38	28	30	39	20
Percent of samples > 15 mg/l	5 %	4 %	5 %	9 %	8 %	3%

* One facility was responsible for this elevated concentration, which skewed the statistics for this year.

Region 4, Los Angeles Regional Water Quality Control Board
(Reporting years 2000 to 2002)

	2000 – 2001	2001 - 2002	2002 – 2003
No. of oil and grease samples	3,502	2,707	2,975
Oil and grease concentration, mg/l			
Minimum	0	0	0
Maximum	1000	1664	1664
Mean (Standard deviation)	13.6 (38.4)	16.8 (66.1)	16.0 (53.2)
Median without zeros	5.8	6.1	6.4
Median counting zeros	5.8	5.4	5.1
Number of O&G samples with concentrations ≥ 15 mg/l	505	484	492
Percent of samples > 15 mg/l	19 %	21 %	19 %

Region 8, Santa Ana Regional Water Quality Control Board
(Reporting years 1997 to 2002)

	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003
No. of oil and grease samples	1,625	1,418	1,450	1,556	1,494	1,427
Oil and grease concentration, mg/l						
Minimum	0	0	0	0	0	0
Maximum	33200	9200	2770	310	1802	923
Mean (Standard deviation)	55* (1048.5)	29 (308.8)	21 (107.5)	13 (23.9)	14 (62.7)	15 (51.5)
Median without zeros	6.5	7	7	6.4	6.0	7
Median counting zeros	5	5	5	5	5	4
Number of O&G samples with concentrations ≥ 15 mg/l	246	233	229	205	176	159
Percent of samples > 15 mg/l	20 %	20 %	21 %	17 %	15 %	17 %

*NOTE: Mean for 1997-1998 = 23.16 if maximum value is excluded.

Reference:

SWRCB (2005). *Annual Report Stormwater Data*. State Water Resources Control Board. February 2005. Posted at: http://www.waterboards.ca.gov/stormwtr/industrial.html

APPENDIX B: ATTACHMENT 3

Industry categories reporting oil and grease concentrations over 400 mg/l*

(Reporting years 1990 to 2004)

Industry	SIC code	Number of samples	Number of facilities	Number of facilities reporting concentrations ≥ 15mg/l	Oil and grease concentration, mg/l	
					Highest value	Second highest value
Lubricating oil	2992	144	29	10	33,200	1300
Fabricated metal products	3499	409	70	19	980	980
Guided missiles and space vehicles	3761	36	5	4	713	573
Flat glass	3211	2	1	1	1640	-
Petroleum bulk stations and terminals	5171	134	42	6	1280	140
Wood office furniture	2521	23	5	1	835	190
Crude petroleum pipelines	4612	20	4	1	580	360
Railroads	4011	84	21	5	9200	1100
Laminated plastics plate, sheet and profile shapes	3083	55	8	1	920	600
Refuse systems	4953	818	172	60	1900	810
Motor vehicle parts, used	5015	771	351	114	1664	823
Scrap and waste materials	5093	740	220	109	643	560
Ship building and repairing	3731	38	8	2	880	28
Search detection navigation, guidance,	3812	36	11	3	928	560
Terminal service facilities for motor vehicle passenger transportation	4173	134	31	11	2770	110
Local trucking	4212	684	161	62	706	698
Trucking, except local	4213	562	171	36	640	413
Concrete products	3272	353	61	21	1802	1000
Miscellaneous non metallic minerals	1499	18	5	1	5440	5
Cement, hydraulic	3241	19	3	1	810	8
Pressed and blown glass	3229	23	5	3	1490	380
Adhesives and sealants	2891	43	26	7	1000	110
Aluminum die and castings	3363	131	34	11	1664	85
Switchgear and switch board apparatus	3613	14	5	1	923	8
Magnetic and recording optical media	3695	23	5	2	530	23
General warehousing and storage	4225	188	59	9	426	375
Metal stampings	3469	104	20	9	676	232
Misc. fabricated wire products	3496	40	9	3	650	140
Electric services	4911	313	52	12	1664	79
Special warehousing and storage	4226	31	9	2	938	38
Local and suburban transit	4111	154	44	18	476	230
Paints, varnishes, lacquers, enamels, and others	2851	224	58	9	400	150
Asphalt felts and coatings	2952	82	22	7	421	88
Bus charter service, except local	4142	36	9	6	413	200
Terminal maintenance for motor freight	4231	230	59	22	413	158
School buses	4151	305	99	24	413	310
Commercial printing, lithographic	2752	72	14	6	470	54
Industrial organic chemicals	2869	60	11	1	420	38
Pottery products	3269	20	5	2	413	20
Copper foundries	3366	10	1	1	450	230
General warehousing and storage	4225	202	61		426	375

Reference:

SWRCB (2005). *Annual Report Stormwater Data*. State Water Resources Control Board. February 2005. Posted at: http://www.waterboards.ca.gov/stormwtr/industrial.html

* Industry categories associated with food or animal fats and oils have not been included

APPENDIX B: ATTACHMENT 4

Highest Ranking Industry Categories based on Maximum, Median and Mean Oil and Grease Concentrations from Statewide and Selected Regional Databases

Industry	SIC Code	Number of facilities Statewide reporting oil and grease data	Number of facilities Statewide reporting oil and grease concentrations ≥ 15 mg/l	Source of data and value in the highest ranks*				
				Statewide Database	Central Coast	San Francisco	Santa Ana	Los Angeles
Lubricating oils and greases	2992	29	10	1, 2, 3		1, 2, 3	1, 2, 3	
Petroleum bulk stations	5171	42	6	1, 2, 3	1, 2, 3	1		2, 3
Bus charter service, except local	4142	9	6	2, 3		1		1, 3
Refuse systems (garbage)	4953	172	60	1	1, 2, 3	1, 2, 3	1, 3	1, 2,3
Scrap and waste materials (salvage yards)	5093	220	109		1, 2, 3	1, 2, 3		1
Local trucking, with storage	4212	161	62		1, 2, 3		1, 2, 3	1
Railroads, line-haul operating	4011	21	5	1, 3		1, 2, 3	1, 2, 3	3
Concrete products, except block & brick	3272	61	21	1, 3		1, 2, 3	1, 2, 3	
Terminal & service facilities for motor vehicle passenger transportation	4173	31	11	1, 3	1	1, 2, 3	1, 3	2
Metal stampings	3469	20	9	3			3	1, 2, 3
Adhesives and sealants	2891	26	7	1, 3			2, 3	1, 3
Pumps and pumping equipment	3561	13	4	2			2, 3	2
Fabricated metal products	3499	70	19	1			1, 3	3
Motor vehicle parts, used	5015	351	114	1	1, 2, 3		1	1

* Industry category was in the highest ranks based on 1 = maximum, 2 = median, 3 = mean oil and grease values

Reference:

SWRCB (2005). *Annual Report Stormwater Data*. State Water Resources Control Board. February 2005. Posted at: http://www.waterboards.ca.gov/stormwtr/industrial.html

APPENDIX C
Annual Runoff Volume, Los Angeles County Watersheds

San Gabriel River *(Stream Gaging Station No. F263C-R)*

Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)
1928-29	2,850	1947-48	8,590	1966-67	62,800	1985-86	31,244
1929-30	3,490	1948-49	6,470	1967-68	26,240	1986-87	21,994
1930-31	2,490	1949-50	4,130	1968-69	274,300	1987-88	23,684
1931-32	13,060	1950-51	558	1969-70	79,110	1988-89	20,899
1932-33	3,040	1951-52	50,900	1970-71	54,590	1989-90	28,677
1933-34	16,950	1952-53	13,880	1971-72	32,740	1990-91	24,904
1934-35	12,190	1953-54	10,990	1972-73	67,020	1991-92	30,460
1935-36	4,590	1954-55	9,250	1973-74	60,500	1992-93	273,200
1936-37*	32,240	1955-56	24,050	1974-75	38,190	1993-94	26,000
1937-38	94,810	1956-57	18,000	1975-76	32,000	1994-95	105,900
1938-39	24,620	1957-58	82,190	1976-77	16,670	1995-96	34,720
1939-40	20,180	1958-59	33,960	1977-78	256,222	1996-97	53,530
1940-41	100,900	1959-60	36,100	1978-79	36,943	1997-98	168,600
1941-42	28,630	1960-61	47,700	1979-80	201,315	1998-99	25,720
1942-43	209,600	1961-62	103,100	1980-81	23,902	1999-00	42,560
1943-44	104,200	1962-63	42,430	1981-82	23,162	2000-01	49,420
1944-45	42,520	1963-64	45,700	1982-83	118,084	2001-02	34,260
1945-46	34,370	1964-65	77,270	1983-84	22,254	2002-03	32,731
1946-47	45,420	1965-66	55,320	1984-85	22,522		

	All years	Last ten years
Minimum	558	25,720
Maximum	274,300	168,600
Mean	53,000	57,000
Standard deviation	61,000	46,000

* Record incomplete

Coyote Creek *(Stream Gaging Station No. F354-R)*

Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)
1963-64	7,950	1973-74	27,700	1983-84	32,043	1993-94*[M]	
1964-65	12,220	1974-75	26,700	1984-85*		1994-95*	
1965-66	23,500	1975-76	17,540	1985-86*		1995-96	30,380
1966-67	27,450	1976-77	27,000	1986-87	24,670	1996-97	52,160
1967-68	19,570	1977-78	92,940	1987-88	33,943	1997-98	97,460
1968-69	64,290	1978-79*		1988-89	32,582	1998-99	25,830
1969-70	16,680	1979-80	91,800	1989-90	13,410	1999-00	24,430
1970-71	23,820	1980-81	24,395	1990-91	35,630	2000-01[E]	51,510
1971-72*		1981-82	40,818	1991-92	44,518	2001-02	17,758
1972-73	43,720	1982-83	89,013	1992-93	106,400	2002-03	84,197

	All years	Last ten years
Minimum	7,950	17,758
Maximum	106,400	106,400
Mean	41,000	53,460
Standard deviation	28,000	31,940

[M] Data missing
[E] Estimate
* Record incomplete

Ballona Creek *(Stream Gaging Station No. F38C-R)*

Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)
1927-28	3,930	1946-47	26,300	1965-66	44,540	1984-85	27,714
1928-29	14,900	1947-48	13,630	1966-67	45,300	1985-86	49,043
1929-30	13,480	1948-49	16,090	1967-68	40,570	1986-87	13,986
1930-31	18,520	1949-50	23,250	1968-69	73,060	1987-88	41,772
1931-32	21,790	1950-51	18,860	1969-70	22,230	1988-89	27,763
1932-33	15,810	1951-52	53,350	1970-71	35,620	1989-90	23,364
1933-34	20,630	1952-53	19,910	1971-72	22,700	1990-91	27,133
1934-35	24,870	1953-54	28,480	1972-73	47,730	1991-92	45,191
1935-36	13,500	1954-55	21,600	1973-74	41,060	1992-93*	
1936-37	40,680	1955-56	34,590	1974-75	34,590	1993-94	28,150
1937-38	52,500	1956-57	22,240	1975-76	22,230	1994-95	74,450
1938-39	28,490	1957-58	43,040	1976-77	27,930	1995-96	38,740
1939-40	21,110	1958-59	13,730	1977-78	81,659	1996-97	39,670
1940-41	67,360	1959-60	17,190	1978-79	43,680	1997-98	80,630
1941-42	17,250	1960-61	12,560	1979-80	70,454	1998-99	30,160
1942-43	34,240	1961-62	50,090	1980-81	20,111	1999-00	44,450
1943-44	33,000	1962-63	21,450	1981-82	29,922	2000-01	62,520
1944-45	24,450	1963-64	18,000	1982-83	86,347	2001-02	26,698
1945-46	18,380	1964-65	27,540	1983-84	26,672	2002-03	55,088

	All years	Last ten years
Minimum	3,930	26,698
Maximum	86,347	80,630
Mean	34,000	48,060
Standard deviation	18,000	19,320

* Record incomplete

Los Angeles River *(Stream Gaging Station No. F319-R)*

Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)
1928-29[E]	9,340	1947-48	52,820	1966-67	171,900	1985-86	244,741
1929-30	12,310	1948-49	44,350	1967-68	125,800	1986-87	118,510
1930-31	14,400	1949-50	42,180	1968-69	832,000	1987-88	176,277
1931-32	50,960	1950-51	36,600	1969-70	92,070	1988-89	141,249
1932-33	22,890	1951-52	212,200	1970-71*	145,300	1989-90	141,594
1933-34	67,860	1952-53	44,490	1971-72	77,560	1990-91	224,410
1934-35	40,470	1953-54	70,790	1972-73	183,300	1991-92	484,849
1935-36	20,470	1954-55	60,120	1973-74	137,800	1992-93	1,122,000
1936-37	91,110	1955-56	96,810	1974-75	115,000	1993-94	187,400
1937-38	408,000	1956-57	48,710	1975-76	72,670	1994-95	740,000
1938-39	82,750	1957-58	191,200	1976-77	101,700	1995-96	189,200
1939-40	65,930	1958-59	49,390	1977-78	668,337	1996-97	216,300
1940-41	369,500	1959-60	49,100	1978-79	274,500	1997-98*	
1941-42	93,390	1960-61	32,000	1979-80	544,632	1998-99*	
1942-43	264,900	1961-62	177,400	1980-81	125,893	1999-00*	24,560
1943-44	217,400	1962-63	54,700	1981-82	178,227	2000-01	293,500
1944-45	100,200	1963-64	47,020	1982-83	758,465	2001-02	131,061
1945-46	91,790	1964-65	76,680	1983-84	120,740	2002-03	229,041
1946-47	106,000	1965-66	247,900	1984-85	118,440		

	All years	Last ten years
Minimum	9,340	131,061
Maximum	1,122,000	1,122,000
Mean	180,000	380,000
Standard deviation	210,000	320,000

[E] Estimate
* Record incomplete

Malibu Creek *(Stream Gaging Station No. F130-R)*

Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)
1930-31*	1,920	1949-50	477	1968-69	119,900	1987-88	17,337
1931-32	14,670	1950-51	56	1969-70	7,200	1988-89	8,876
1932-33	9,190	1951-52	58,200	1970-71	17,300	1989-90*	
1933-34	12,370	1952-53	2,940	1971-72	4,340	1990-91	14,872
1934-35	6,220	1953-54	4,990	1972-73	25,400	1991-92	67,330
1935-36	2,310	1954-55	758	1973-74	15,910	1992-93*	
1936-37	23,940	1955-56	4,680	1974-75	11,020	1993-94	11,090
1937-38	34,100	1956-57	444	1975-76	3,910	1994-95	68,700
1938-39	4,630	1957-58	31,660	1976-77	4,980	1995-96	9,395
1939-40	6,100	1958-59	1,510	1977-78	80,990	1996-97	31,180
1940-41	73,220	1959-60	504	1978-79	33,408	1997-98	81,700
1941-42	1,820	1960-61	99	1979-80*		1998-99	7,430
1942-43	47,600	1961-62	26,150	1980-81	9,832	1999-00	16,440
1943-44	30,170	1962-63	701	1981-82	10,031	2000-01	38,920
1944-45	4,240	1963-64	384	1982-83	88,148	2001-02	7,670
1945-46	3,800	1964-65	1,560	1983-84	17,411	2002-03	18,761
1946-47	3,820	1965-66	37,520	1984-85	12,002		
1947-48	177	1966-67	25,700	1985-86	27,881		
1948-49	90	1967-68	13,430	1986-87	6,236		

	All years	Last ten years
Minimum	56	7,430
Maximum	119,900	81,700
Mean	20,000	29,100
Standard deviation	25,000	26,600

* Record incomplete

Santa Clara River *(Stream Gaging Station No. F92-R)*

Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)	Season	Total Runoff (acre-ft)
1930-31	1,890	1948-49	1,300	1966-67	7,100	1984-85	13,558
1931-32	4,280	1949-50	888	1967-68	3,070	1985-86	17,896
1932-33	488	1950-51	217	1968-69[E]	30,170	1986-87	10,197
1933-34	1,600	1951-52	16,760	1969-70	9,610	1987-88	11,981
1934-35	1,090	1952-53	592	1970-71	10,930	1988-89	8,535
1935-36	1,590	1953-54	1,160	1971-72	6,640	1989-90	8,864
1936-37	4,850	1954-55	612	1972-73	9,450	1990-91	10,058
1937-38	26,900	1955-56	1,000	1973-74	6,600	1991-92*	
1938-39	10,410	1956-57	1,020	1974-75	3,910	1992-93*	
1939-40	1,570	1957-58	10,620	1975-76	2,710	1993-94*	
1940-41	41,320	1958-59	940	1976-77	2,750	1994-95*	
1941-42	23,400	1959-60	288	1977-78*		1995-96*	
1942-43	47,170	1960-61	533	1978-79	11,617	1996-97	6,190
1943-44	49,770	1961-62	10,470	1979-80*		1997-98	53,800
1944-45	11,050	1962-63	965	1980-81[NR]		1998-99	11,330
1945-46	6,440	1963-64	780	1981-82[NR]		1999-00	13,600
1946-47	11,150	1964-65	1,550	1982-83	83,154	2000-01	5,620
1947-48	2,270	1965-66	15,990	1983-84*		2001-02	2,350

	All years	Last ten years
Minimum	217	2,350
Maximum	83,154	53,800
Mean	10,000	13,200
Standard deviation	20,000	14,600

Reference:

LADPW (2004). *Los Angeles County 2002-2003 Hydrologic Report, Stream Gaging Station Peak Flow*. Los Angeles County Department of Public Works. Posted at: http://ladpw.org/wrd/report/0203/runoff/peak.cfm.

[E] Estimate
* Record incomplete.
[NR] No record.

APPENDIX D
Estimated Mass Loading Calculations for Los Angeles County Watersheds

Conversion factors:

1 acre-foot = 1,233,481.85532 liter
1 pound = 453,592.37 mg
0.885 g/ml = density of used oil (Environment Canada, 2005)
1 ml = 0.0002642 gallon

1	Runoff, in liters = Runoff volume (acre-ft) x 1233482 (l/acre-ft)
2	Loading, in mg = Runoff, in l x Average annual mean concentration
3	Loading, in lbs = Loading, in mg/453592.37 mg/lb
4	Volume of used oil, in gal = [(Loading, in mg/1,000 mg/g)/ 0.885 g/ml] x 0.0002642 gal/ml
5	Unit load = Loading, in lbs/No. of urban acres in watershed

Calculations:

			Minimum	Average	Maximum
	San Gabriel River				
	Average annual concentration, mg/l	1.9			
	Runoff volume, in acre-ft (Appendix C)		25,720	57,000	168,600
1	Runoff volume, in l		31,725,157,040	70,308,474,000	207,965,065,200
	#1, rounded off		32,000,000,000	70,000,000,000	210,000,000,000
2	Estimated loading, in mg		60,800,000,000	133,000,000,000	399,000,000,000
3	Estimated loading, in lbs		134,041	293,215	879,644
	#3, rounded off		130,000	290,000	880,000
4	Volume of used oil, in gal		18,151	39,705	119,114
	#4, rounded off		18,000	40,000	120,000
5	Unit load, lbs/acre		0.9	2.1	6.2
	Coyote Creek				
	Average annual concentration, mg/l	3			
	Runoff volume, in acre-ft (Appendix C)		17,758	53,460	106,400
1	Runoff volume, in l		21,904,173,356	65,941,947,720	131,242,484,800
	#1, rounded off		21,900,000,000	65,940,000,000	131,200,000,000
2	Estimated loading, in mg		65,700,000,000	197,820,000,000	393,600,000,000
3	Estimated loading, in lbs		144,844	436,118	867,739
	#3, rounded off		100,000	400,000	900,000
4	Volume of used oil, in gal		19,613	59,055	117,502
	#4, rounded off		20,000	60,000	100,000
5	Unit load, lbs/acre		*No unit load was calculated for Coyote Creek; urban acreage draining into watershed was not readily available.*		
	Ballona Creek				
	Average annual concentration, mg/l	3.6			
	Runoff volume, in acre-ft (Appendix C)		26,698	48,060	80,630
1	Runoff volume, in l		32,931,502,436	59,281,144,920	99,455,653,660
	#1, rounded off		32,930,000,000	59,280,000,000	99,460,000,000
2	Estimated loading, in mg		118,548,000,000	213,408,000,000	358,056,000,000
3	Estimated loading, in lbs		261,354	470,484	789,378
	#3, rounded off		260,000	470,000	790,000
4	Volume of used oil, in gal		35,390	63,709	106,891
	#4, rounded off		35,000	64,000	110,000
5	Unit load, lbs/acre		6.3	11	19

	Los Angeles River				
	Average annual concentration, mg/l	3.08			
	Runoff volume, in acre-ft (Appendix C)		131,061	380,000	1,122,000
1	Runoff volume, in l		161,661,384,402	468,723,160,000	1,383,966,804,000
	#1, rounded off		160,000,000,000	470,000,000,000	1,400,000,000,000
2	Estimated loading, in mg		492,800,000,000	1,447,600,000,000	4,312,000,000,000
3	Estimated loading, in lbs		1,086,438	3,191,412	9,506,333
	#3, rounded off		1,100,000	3,200,000	9,500,000
4	Volume of used oil, in gal		147,116	432,154	1,287,266
	#4, rounded off		150,000	430,000	1,300,000
5	Unit load, lbs/acre		3.73	10.9	32.2
	Malibu Creek				
	Average annual concentration, mg/l	2.5			
	Runoff volume, in acre-ft (Appendix C)		7,430	29,100	81,700
1	Runoff volume, in l		9,164,771,260	35,894,326,200	100,775,479,400
	#1, rounded off		9,160,000,000	35,900,000,000	101,000,000,000
2	Estimated loading, in mg		22,900,000,000	89,750,000,000	252,500,000,000
3	Estimated loading, in lbs		50,486	197,865	556,667
	#3, rounded off		50,000	200,000	560,000
4	Volume of used oil, in gal		6,836	26,793	75,379
	#4, rounded off		6,800	27,000	75,000
5	Unit load, lbs/acre		5.0	20	56
	Santa Clara River				
	Average annual concentration, mg/l	2.40			
	Runoff volume, in acre-ft (Appendix C)		2,350	13,200	53,800
1	Runoff volume, in l		2,898,682,700	16,281,962,400	66,361,331,600
	#1, rounded off		2,900,000,000	16,300,000,000	66,400,000,000
2	Estimated loading, in mg		6,960,000,000	39,120,000,000	159,360,000,000
3	Estimated loading, in lbs		15,344	86,245	351,329
	#3, rounded off		15,300	86,200	351,000
4	Volume of used oil, in gal		2,078	11,679	47,574
	#4, rounded off		2,080	11,700	47,600
5	Unit load, lbs/acre		0.97	5.46	22.2

References:

Environment Canada (2005). *ETC Spills Technology Databases, Oil Properties Database: Lubricating oil (Engine, Gasoline)*. Posted at: www.etc-cte.ec.gc.ca/databases/OilProperties/Default.aspx.

LADPW (2005). *Los Angeles County 1994-2005 Integrated Receiving Water Impacts. Final Report*. Los Angeles County Department of Public Works. August 2005. Posted at: http://ladpw.org/wmd/NPDES/report_directory.cfm.